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ANALYSIS OF PROGENY RECORDS IN LACOMBE SWINE

by

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A THESIS
SUBMITTED TO THE FACULTY OF GRADUATE STUDIES
IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE
OF MASTER OF SCIENCE

DEPARTMENT OF ANIMAL SCIENCE

EDMONTON, ALBERTA
SEPTEMBER, 1966

UNIVERSITY OF ALBERTA

FACULTY OF GRADUATE STUDIES

The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies for acceptance, a thesis entitled "Analysis of Progeny Records in Lacombe Swine" submitted by Tong Kiat Tan, B.Sc., in partial fulfilment of the requirements for the degree of Master of Science.

ABSTRACT

The records of 1672 litters tested from 1958 to 1965 under the Canadian Record of Performance Policy for Lacombe swine were taken for analysis.

No trends of improvement were apparent during the period studied.

With the exception of loin area, no significant differences were found between performance in home and station testings. Provincial effects were also not considered a major factor in obscuring possible genetic gain.

Among test litters, 48% were by sib tested sires and 51% out of sib tested dams. The frequencies of matings in which both or neither of the parents were sib tested were higher than would have been expected under random mating. In 74% of the matings the sires were selected from outside the herd in which their progeny were tested while in only 31% of the matings were the dams selected from outside the herd.

All the evidence considered showed that the sires selected had higher average sib tests than the general population, especially for loin area. No selection was evident for dams.

Correlations between progeny and parental sibs were generally higher when progeny and parental sibs were from the same herd. No consistent results were evident to show which test, home or station, more accurately indicated progeny performance. Most correlations were statistically significant but were generally too low to be of good predictive value.

Heritabilities were estimated from progeny-parental sib regressions.

The heritability values were generally lower than in other studies and zero for loin area when estimates were based on progeny-parental sib regressions in which the sire's sibs and progeny were reared in different herds.

Especially under intense selection, boars may have been chosen from litters in which those remaining were inferior to the tested sibs. This could have occurred with sufficient frequency to explain the ineffectiveness of sire selections based on full sib records. Between-herd environmental differences could also have contributed to errors in selection.

ACKNOWLEDGMENTS

The author wishes to thank Dr. L.W. McElroy, Head of the Department of Animal Science, for making available the facilities of the department for this study. Special thanks are granted to Dr. H.T. Fredeen, Head of Livestock Research, Lacombe Experimental Farm and Secretary of the Canadian Lacombe Breeder's Association for making the data for this study available and for valuable and appreciated suggestions. The cooperation and assistance of Lacombe Experimental Farm is gratefully acknowledged. I am particularly indebted to my advisor, Dr. W. Combs, Assistant Professor of Animal Genetics for helpful criticisms and suggestions during the course of study and in the preparation of the manuscript. The assistance of Dr. R.T. Hardin, Assistant Professor of Poultry Genetics for suggestions regarding statistical treatment of the data is gratefully acknowledged.

Thanks are also extended to Dr. K.W. Smillie, Associate Professor of Computing Science, Miss M. Smit, and Mr. C.C. Chiang for assistance in programming the statistical analysis of the data by electronic computer.

Many thanks are due to my wife, Swee, for encouragement throughout the course of study. The assistance given by Miss Sandra Popik for the final typing of this manuscript is gratefully appreciated.

The financial assistance of the External Aid Office in Ottawa, without which this work could not have been done, is gratefully acknowledged.

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INTRODUCTION

Progeny tests have been a part of the program of swine improvement for a long period of time. The term, "progeny test", as applied to animal breeding refers to the estimation of an individual's breeding value by measuring the qualitites or performance of the offspring. Since the sows and boars which are to be used for breeding purposes can not themselves be killed at normal market weights, data on their own ability to produce desirable carcasses can not be directly obtained. The validity of appraisal by progeny test is based on the assumption that information on the progeny gives a reliable estimate of the genetic composition of the parents and their ability to transmit the desired traits. It is also assumed that the testing results would indicate how the full sibs of the tested animals will produce. Since the full sibs of the tested animals are frequently retained for breeding, it is desirable to study test performance as a predictive measure of full sib breeding value. This is of particular importance to the practical application of swine progeny testing since selection can be based on sib records especially for carcass traits which cannot be measured on live animals or for lowly heritable traits.

In this study, the main object was to determine by correlation and regression analysis whether or not the measurements of the parental full sib records would be indicative of progeny performance in the Lacombe breed. Heritabilities were also estimated on offspring-parent relationships for the traits studied. Trends during the period studied and the use of the testing records were examined to evaluate the effectiveness of the selective registration procedures in the Lacombe breed.

LITERATURE REVIEW

I. HISTORY AND DEVELOPMENT OF SWINE TESTING

A. Countries other than Canada

Different plans of progeny testing have been used in many different countries since first established in Denmark in 1907. Though the choice of a plan of testing of swine in a country depends on geographical features, types of pigs and market demands, the aim of assisting breeders in finding boars and sows which produce the most valuable offspring has been the same.

At the close of the last century, systematic work had already begun in Denmark to improve a type of swine suitable for the export market and fit for the climatic and farm conditions of the country (Lush, 1936). Soon after 1896, a number of progeny tests of various kinds were conducted in several privately owned "breeding centres" which were operated under supervision and veterinary care of a district committee. This committee was not appointed by the government but it's members were elected by the cooperative bacon factories, the farmers' associations, and the small-holders' associations. They advised breeders about their breeding program and made sure that the pedigree and other records were carefully kept. Scoring of the outward appearance of the swine and the offspring used in breeding centers was found inadequate. Some kind of actual slaughter test was thought necessary to improve the breed and its ability to produce a good quality of bacon efficiently for the purpose of increasing the market of Danish bacon in Britain. Therefore, by 1907, it was decided to start a system of official progeny testing stations. Since then, the general principles and procedures in which four pigs of a litter, two of each sex, were finished and slaughtered at market weight under standardized conditions of

management and feeding in the testing stations have not been changed although some changes have been made occasionally in the feeding and handling of the pigs.

Since 1920, progeny testing of pigs has spread to other countries in Scandinavia, the continent of Europe, New Zealand, Australia, and more recently to Britain. The scheme was modified to meet the conditions in each country.

B. In Canada

Although the example of progeny testing work in Scandinavian countries gave a lead, the geographic features of this country and distances demanded the development of a policy to suit Canadian conditions. An early stage of swine testing by scoring the sows through the performance of their progeny was first conducted in 1922. Special consideration was given to conformation and weight thought desirable for the production of bacon (Stothart, 1937).

In 1928, a further plan called "Advanced Registry Policy for Swine" with enlarged scope was proposed after extensive research into the plans of pig recording and testing in other countries for establishing a broader and more permanent program of improvement. The sows from breeders of purebred swine in Canada who regularly maintained herds of not less than three sows and a herd boar could be tested for eligibility for registration in the Advanced Registry. Minimum standards for registration were set for growth, efficiency of feed utilization and carcass quality.

This policy has been operated under three main principles: (1) purebred swine are tested for their commercial value, (2) a pedigree based on performance will be developed , thus (3) providing the swine breeder with a service parallel to that provided the breeder of dairy cattle and

the poultry breeder through the agency of the Record of Performance (Peterson, 1938).

Testing stations were not established until 1934 since it was thought too costly to have many stations or to ship long distances to stations for testing. Because (1) many farmers with large herds, particularly in Western Canada, had not the facilities to maintain small groups of pigs of varying ages in separate pens and to give them the necessary attention a comparative test during different seasons of the year; (2) pigs were fed on a variety of feeds by various methods; and (3) the home feeding plan did not permit keeping on feed consumption records (Peterson, 1938), it soon became apparent that stations were necessary for obtaining accurate records of performance and to overcome some of these difficulties. In 1934, four stations were established for these purposes. At the present time, there are eight stations across Canada.

The Advanced Registry Swine Policy was revised slightly in 1959. Lower backfat and higher belly grade standards were established. The name of the policy was changed to "Record of Performance" to conform with those applied to other classes of livestock under performance testing.

Since the Lacombe breed was selected on the basis of performance in each generation during the course of its development from 1947 to 1957 at Lacombe Experimental Farm, similar selection standards in the registration requirements of this breed were considered desirable. A newly formed Canadian Lacombe Breeders' Association in 1959 approved a constitution including rules and regulations governing selective registration for the breed. Gilts are eligible for registration if they are from registered parents, free from abnormalities and are representative of the breed type. A boar is eligible for registration if his full sibs have attained

required standards under R.O.P. tests; if he is by an "Elite" sire and out of an "Elite" dam (i.e. the sows or boars whose litters have met the registration standards), or; if he is out of an "Elite" dam and by a boar out of a litter which has tested 10 per cent above the required standards (also see Appendix A).

II. GENERAL CONSIDERATIONS OF PROCEDURES OF R.O.P. TESTING

It is essential that the test, for the purpose of assisting the breeders in finding superior breeding stock through their progeny performance be directly related to commercial value, have great accuracy, and be acceptable to, and useable by breeders (Fredeen, 1965a). Various studies have been conducted on assessing the value and accuracy of the present R.O.P. program.

A. Carcass Evaluation Procedures

In R.O.P. programs, the appraisal of hog carcass quality provides detailed carcass information related to commercial value for use in the selective improvement of breeding stock. The standards of length, carcass backfat thickness, total carcass scores, and measurement of loin-eye muscle are used as predictors of leanness which must be considered the most important single factor in hog carcass evaluation though other factors, such as flavor, color, texture, and tenderness also influence carcass quality. Extensive research has been done on evaluating the usefulness and accuracy of the carcass measurements as more carcass information becomes available.

Until 1965, measurements of length (20 points), backfat thickness (30 points) and loin-eye muscle area (30 points) and belly quality (20

points) within three weight classes provided the basis of a total score of carcass quality in Canadian Record of Performance testings. Fredeen (1965a) reported that the total carcass score was shown to have reliability equivalent to that of the total of the backfat measurements. R.O.P. score was also found highly correlated to the lean cut index (r=0.79), lean cut index being the ratio of trimmed to untrimmed lean cuts, and the wholesale cut value (r=0.71) (Spurr, 1965). In the same study, R.O.P. score was also related to carcass length (r=0.49), total backfat (r=-0.87), loin area (r=0.52), and belly grade (r=0.84). This indicated that R.O.P. score could be reliable as a predictor of leanness of the carcass and is considered as a reasonable index of carcass quality.

a. Carcass length

Although carcass length is popularly believed to be associated with the carcass quality, most studies indicate that length bears only a small relationship with per cent lean cuts and is not a useful predictor of carcass merit (Crampton, 1940; Bowman *et al.*, 1962b; Buck *et al.*, 1962; Sinclair and Murray, 1935; Fredeen *et al.*, 1964 and 1965a). Carcass length was found to be correlated with R.O.P. score (r=0.49), but less predictive of per cent lean cuts (r=0.26) and lean cut index (r=0.28) (Spurr, 1965). This indicates that the emphasis placed on length should be placed on other more meaningful measures of carcass merit.

b. Backfat thickness

R.O.P. carcass backfat measurement is the average of measures of the maximum point at the shoulder, minimum point at the mid-back, and maximum fat over the loin of the split carcass. During the years of

present study, only the shoulder and loin measurements were used for R.O.P. scoring. Early work of Scott (1930), in comparing numerous correlations between various factors (length of carcass, weight of carcass, and depth of fat) and per cent yield of various cuts, brought out the fact that the covering of fat carried by a hog was a most important factor in determining the per cent of the wholesale cuts that its carcass would yield. Hammond (1933) suggested that the cross-section of the *m. longissimus dorsi* or "eye" muscle in area and depth and the fat adjacent to it could be used as indices of the total carcass leanness and fatness. In an early experimental validation of backfat as an index of carcass fatness, Hankins and Ellis (1934) found that the correlation between average backfat thickness measured at five specific points and the fat content (ether extract) of the edible pork cut was $r=0.84 \pm 0.04$. In a study of the variations of muscle, fat, and bone, Aunan and Winters (1949) found significant correlations between average backfat (at the thickest and thinnest points, and at a point level with the seventh rib) and total lean meat in whole carcass ($r=-0.63$), and total fat ($r= 0.79$).

Fredeen *et al.*, (1964) reported that total backfat (sum of maximum shoulder, minimum back, and maximum loin) accounted for 54% of the total variance in per cent lean cuts. Bowman *et al.* (1962b) found a correlation ($r^2=0.36$) between carcass backfat and per cent lean. Negative and highly significant correlations were found between total backfat measurements and R.O.P. score ($r=-0.87$), per cent lean cuts ($r=-0.67$) and lean cut index ($r=-0.79$) (Spurr, 1965). Various measurements of backfat thickness at different sites have been compared to find a simple measurement or combination of measurements that accurately estimate carcass merit. McMeekan (1941) found shoulder backfat to be less accurate than mid-backfat and the latter

less accurate than measures of fatness in the loin region. The mean back-fat (mean of shoulder, mid-back, loin) was the best of all measures along the back line. This was in agreement with later studies by Kielanowski and Osinska (1954), Harrington (1958), and Buck _et_ _al_. (1962).

c. Loin-eye area

Prior to 1946, the loin-eye area was determined as the product of length by width of the loin-eye muscle. Since then, loin-eye area is obtained by planimeter measurement of a tracing of the cross-section of the _m_. _longissimus_ _dorsi_ muscle at the last thoracic vertebrae. Thickness of loin-eye muscle at the last rib was widely used as an indication of the relative amount of lean meat throughout the carcass. McMeeken (1941) reported that the depth of loin-eye muscle taken alone was a relatively poor index of carcass leanness, but the product of length and depth of the loin-eye muscle was better related to the lean content of the carcass (r=0.84). Loin-eye area was found significantly correlated with R.O.P. score (r=0.52), per cent lean cuts (r=0.54) and lean cut index (r=0.53) by Spurr (1965). However, no significant correlations were found in the studies of Aunan and Winters (1949), and Crampton (1940), between loin-eye area and leanness of the carcass. But, it was highly significant when the effect of carcass weight was removed in Aunan and Winters' study. In most of the cases, loin-eye area has been found to be a good indicator of carcass leanness (Pearson _et_ _al_., 1956a; Harrington, 1958; Henry _et_ _al_., 1963; Kline and Hazel, 1955). Planimeter area of a cross-section of the loin muscle taken at the last rib was also found to be highly correlated with the per cent lean in the ham. The latter was somewhat more reliable than loin area as an over-all measure of carcass lean (Fredeen, _et_ _al_., 1955b).

d. Belly grade

Bellies are graded as Excellent (A), Good (B), Fair (C), or Poor (D) according to thickness and distribution of the layers of fat and lean. High correlations were reported by Spurr (1965) between belly grade and per cent lean cuts (r=0.74) and lean cut index (r=0.70).

Fredeen (1965a), in a memorandum prepared for the Alberta R.O.P. committee, pointed out that, though present total R.O.P. carcass score and average backfat thickness were equally reliable for estimating carcass merit, the ratio of loin area to average backfat thickness or total backfat would be better predictive of per cent yield of lean cuts than either of the other two. Therefore, loin/fat ratio was included in this study. Fredeen _et al_. (1964) found 53 per cent of the total variance of per cent lean cuts was explained by ratio of loin area to total backfat. The loin/fat ratio was also found to be positively correlated with per cent lean cuts (r=0.70) and lean cut index (r=0.79) (Spurr, 1965). Bratzler _et al_., (1947) indicated that the loin/backfat ratio was a reliable index for estimating the yield of primal cuts from a half carcass (r=0.82),

B. Size of the Test Group

In Canada, four pigs are tested from each litter entered on test. The optimum group size in progeny testing has been discussed by Robertson (1957). He pointed out that the capacity of the facilities and the number of sires to be selected each generation determined the group size. For many years, in most countries, four pigs per litter, two of each sex, were thought to be adequate for testing (Hellberg, 1938; Osteroff, 1956; Roitsch, 1961). However, Csire (1962) reported that two pigs per litter were sufficient to determine rate of gain. It is generally realized that

the pigs tested in a litter should be in quantitites sufficient to provide an accurate measure of the performance of the entire litter.

Unfortunately, the larger the tested group, the smaller the potential breeding stock remaining for selection. This affects the selection differential and consequently, influences the rate of improvement. Fredeen (1954) suggested that two pigs for slaughter test would be sufficient for getting maximum test reliability and minimum loss of breeding stock. He further pointed out that these two pigs should be males because the need for replacement boars was considerably less than the need for replacement gilts.

C. The Value and Interpretation of Feed Records

In R.O.P. testing, the animals are fed as a group. This is the simplest procedure from the standpoint of equipment needed and labor costs, but it introduces complications in the interpretation of results. Fredeen and Jonsson (1957) and Fredeen (1965a) pointed out that competition between pigs in a litter, wastage of feeds, the health and thrift of individual pigs and of the litter at the start of test or during test limited the accuracy of the measurement of feed utilization under group testing. The difficulty is increased when an animal, owing to accident or other unavoidable cause, has to be removed from the test. These sources of variation associated with group feeding could be reduced or eliminated by individual feeding which provides a record of within-litter variation in feed consumption. Consequently, it provides a much more reliable estimate of feed conversion for each litter tested (Fredeen and Jonsson, 1957; Jonsson, 1959). With the realization of these variations concerned with group feeding, individual feeding of each test pig is used in several

countries (Jonsson, 1959; Duckworth *et al*., 1961; Buck *et al*., 1962).

III. EFFECTS OF ENVIRONMENT ON PERFORMANCE

Since it has been well established that environment plays an important part in any progeny or performance testing, the role of environment should not be underestimated when individuals are tested under inconsistent environmental conditions.

A. Station Differences

Lush (1936), in an analysis of Danish swine progeny tests, found important differences in daily gain and belly thickness at different testing stations. This might have arisen from the variation either in management or in pig populations in the different districts. Station differences in carcass length and backfat thickness were too small to be important although statistically significant (2.2% and 0.5% of total variance respectively). Fredeen and Jonsson (1957) in a study of three Danish progeny station testing records of 936 Danish Landrace litters tested under a system of individual feeding found only small station differences in carcass measurements of length, backfat thickness, feed efficiency and daily gain. In another Danish swine progeny test study, Jonsson and King (1962) reported that only a small proportion of the total variation was due to breeding center differences.

Johansson and Korkman (1951) in an analysis of Swedish pig testing station records over 14 years found significant and important station differences in age at slaughter, firmness of fat, and size and shape of ham, but possibly due to different standards of scoring. Only 2.3%, 1.1%, and 2.5% of the total variance, respectively, were caused by station

differences in length of carcass, daily gain, and backfat thickness.

Most of the studies of the records of Advanced Registry test stations in Canada have indicated that regional variations exist.

Stothart (1937) in his study of testing records of 370 Canadian Yorkshire litters over a six-year period demonstrated highly significant differences in most of the characters among different stations. Significant differences were also found among stations in average carcass score, feed economy, length of carcass, and loin area in his further analysis in 1938. Fredeen (1953) found similar results in an analysis of Canadian Yorkshire test records from 1939-1950; he considered that the greater differences between stations as contrasted with those found under Danish and Swedish conditions might be due to strain differences in the Canadian Yorkshire or arise from differences in climate, quality of feed or in several other environmental factors that were likely to be more important in such widely separated testing stations in Canada. Since no evidence was found by Fredeen (1964) of strain formation within the Yorkshire, it is probable that station differences are largely environmental.

B. Home Versus Station Testing

To complement home testing, R.O.P. station testing was initiated to obtain accurate data of feed consumption which was not always reliable under home testing and to attain more-uniform slaughter weights at the station. Since test stations were designed for standard feeding and management, it was thought that station testings would provide a more valid basis for comparing herds, but Lefebvre (1938) reported that the carcass measurements of pigs fed at home and at the station did not differ significantly within herds during the same period of time. Fredeen (1965a) also

noted that for appraising carcass merit, home testings could provide as valid a basis for between-herd comparisons as could station testings. Furthermore, post-weaning performance was found by Fredeen and Plank (1963) to be definitely influenced by pre-weaning performance. Jonsson and King (1962), in a study of variation in Danish progeny tests, demonstrated that small contributions from the pre-test environment could reduce the accuracy of selection although the effect was not found significant in most of the traits in the sample examined. These differences in management, health and nutrition in different herds before test continued influencing the performance during the whole period of test. This problem could not be solved by station testing and lead to the conclusion that station testing was unlikely to be superior to home testing. Valid comparisons can be made if the performance of each pig or litter is expressed as a percentage of its own herd average (Fredeen, 1965a).

C. Year Differences

Stothart (1937) indicated that most of the characters measured under the Advanced Registry were influenced by differences due to years. The variance between years was highly significant for all of the seven traits studied in Swedish swine progeny testing (Johanson and Korkman, 1951). Fredeen (1953) demonstrated that province and year differences accounted for 7-18% of the total variance for all traits except loin area and feed economy (61.5% and 56.7% respectively). The high contribution of province and year differences to the total variance in loin area might be due to the change made in 1946 in the method of measuring this trait. Prior to this time loin-eye area was simply the product of length and width of the loin eye. In a Danish study, Fredeen and Jonsson (1957) found that the

contribution of years to the total variance was small for three traits studied but relatively large for backfat.

D. Seasonal Differences

Nutritionists have demonstrated that extremely hot or cold weather increases the maintenance requirements of animals, lowering the feed efficiency. Such differences in maintenance requirements due to varying temperatures in different seasons may be expected to influence performance in any swine testing.

Evvard _et_ _al_. (1927) found that fall-fed pigs in central Iowa required more feed per 100 lb. gain than did spring-fed pigs. Seasonal differences were also found to be significant in daily gain and carcass characters by Blunn and Baker (1947). Crampton and Ashton (1946) found that, if pigs were finished in winter in cold pens, the rate of gain was sufficiently reduced to result in a leaner carcass. Pigs raised in the fall had lower rates of gain than in the spring, and more backfat was reported in fall-fed pigs. No significant seasonal differences were reported in a study of Swedish swine progeny testing (Johansson and Korkman, 1951).

Differences between tests carried out in summer and those in winter were not significant in most of the traits except shoulder fat (Duckworth _et_ _al_., 1961), but when considering the overall average for summer and winter testing, better growth was found in summer than in winter. Plank (1961) indicated that pigs had slower gain and poorer feed efficiency in the winter season. This was likely due to lower maintenance requirements in the summer season.

E. Other Environmental Factors

While self-feeding is practiced at test stations, the breeder may follow his own feeding practices in home testing. In comparing self-feeding and hand-feeding in Canadian Yorkshire swine, Crampton (1937) pointed out that the carcasses of the two groups under different feeding systems were not significantly different except that the carcasses of self-fed pigs were shorter than those of hand-fed pigs. Other studies have established that restriction of feed intake during the finishing period resulted in leaner carcasses (Tribble _et_ _al_., 1956; Crampton _et_ _al_., 1954; Plank, 1961; Salmela _et_ _al_., 1963). Berg and Bowland (1958) showed that restriction of feed intake reduced growth rate but improved carcass quality and feed efficiency. But, Bowland (1961) reported that no improvement in feed utilization or in carcass grades was obtained by restricted feeding when compared to full feeding.

Many workers have reported that plane of nutrition has a considerable influence on carcass performance (McMeekan, 1940; Winters _et_ _al_., 1949; Cummings and Winters, 1951; Brugman, 1950; Berg and Plank, 1961). However, Fredeen (1953) pointed out that under the Advanced Registry testing program in Canada where the same standardized rations were fed at all stations, nutrition seemed unlikely to be the important source of variation among station tested pigs.

IV. EFFECT OF SEX ON PERFORMANCE

Among farm animals, the females usually grow more slowly during some stages of development. Russell (1930) found that barrows gained 5.4% faster than the females. Berge (1936) stated that females required 4.86

days longer than barrows to increase in weight from 20 to 90 kg. Bennett and Coles (1946) in an analysis of R.O.P. records of Canadian Yorkshire litters from 1942-45 demonstrated that barrows had a significantly larger daily rate of gain. They further suggested that the sex differences were sufficiently great to require equal numbers of males and females in each progeny testing group. These results have been confirmed by Fredeen (1953). Miranda et al. (1946) analyzed the data collected in the first ten years of The Record of Performance of swine at the Iowa Agricultural Experiment Station and found that sex had a small but real influence on rate of gain. Only a slight difference between the sexes was reported in regard to rate of gain by Johansson and Korkman (1951), and Lush (1936) found no significant difference between sexes in rate of gain. On the other hand, a few reports have indicated that females were superior in growth rate to males (Duckworth et al., 1961; Jonnson and King, 1962). Although small or even no effect of sex has been reported, the superiority of rate of gain for males over females has been in good agreement in most studies (Bengtsson, 1934; Indrebo, 1954; Crampton and Ashton, 1945; Berg and Bowland, 1958; Reddy et al., 1959; Plank, 1961).

Sex differences were also reported in carcass quality. Scott (1930) showed that gilts were superior in carcass quality to barrows. Lacy (1932) in a study of slaughter data from swine records at the Iowa Agricultural Experiment Station reported that barrows gained faster than gilts but on the average gilts had more ham and loin and about the same proportion of belly. Barrows carried more fat. More fat in carcasses from barrows was also reported by Warner et al. (1934) in a study of fatness of swine at the U.S.D.A. Experimental Farm at Beltsville. Similar results were also reported by Reddy et al. (1959).

In an early study of Danish progeny testing, Lush (1936) found statistically significant effects of sex differences in thickness of backfat and body length, but the effect of sex on body length was small compared with other sources of variation. Consistently important differences between sexes were reported in another analysis of Danish swine R.O.P. testing (Fredeen and Jonsson, 1957; Jonnsson and King, 1962).

In Sweden, Jarl (1939), investigating factors affecting the quality of pork indicated that bellies from gilt carcasses were thicker and higher in content of fat than those from barrows. Johansson and Korkman (1951) found about 17% of the total variance in body length was caused by sex differences, gilts having 1.1 cm. longer carcasses than barrows. For other carcass characters, 18.1%, 14.1%, 33.6%, 32.8% of the total variance was contributed by sex differences in thickness of belly, firmness of fat, size and shape of ham, and thickness of backfat, respectively.

The work of Duckworth et al. (1961) at Wye College, University of London, demonstrated that female pigs were significantly superior in all carcass measurements. In a study of 250 pigs raised at the stations in England, Buck et al. (1962) reported that gilts were leaner than the hogs (barrows) in terms of higher percentage of lean meat, larger loin eye muscle, and smaller measurements of backfat thickness.

Crampton (1942) in a nutritional study at McGill University found that males had fatter carcasses than females regardless of ration. The female carcasses obtained a significantly higher average score for general excellence in terms of larger loin muscle, thinner backfat, and thicker bellies. In later studies, Crampton and Ashton (1945; 1946) indicated that at equal market weight (or carcass weight) males were somewhat fatter than females. Work at the University of Alberta either in breeding or nutrition

studies had shown similar results (Hull, 1940; Berg and Bowland, 1958; Bowland, 1959; Berg and Plank, 1961; Plank, 1961; Bowland,1963), but Bowland and Berg (1959) reported that sexes did not differ appreciably in length of carcass and in carcass grade. Spurr (1965), in a study of carcass characteristics of crossbred pigs, found that sex was a major influence on carcass quality. Gilts were superior in length, backfat, and higher proportion of the four trimmed lean cuts (ham, loin, picnic shoulder, and Boston butt). These differences contributed to a higher wholesale cut out value per cwt. of female carcasses.

In Canada, Bennett and Coles (1946), in an analysis of carcass data on 154 males and 127 female Yorkshire pigs taken at swine progeny testing stations, found significant sex differences for nearly all carcass characteristics. Carcasses from females were longer, heavier in shoulder, lighter in middle, heavier in ham and larger in area of loin-eye muscle than were carcasses from males. Fredeen (1953) showed that female carcasses had 0.23 in. more length, 0.11 in. less fat along the back, 0.57% more ham and 0.53 sq. in. more loin-eye area than barrows. All these superiorities of female carcasses resulted in 6-8% higher R.O.P. carcass scores in gilts than in barrows. Fredeen and Lambroughton (1956) also found that gilts were consistently superior to barrows in all carcass measurements and scores. Further analysis of the R.O.P. records under Advanced Registry of purebred swine all confirmed that female carcasses were superior in most of the characters studied (Fredeen *et al.*, 1955a and 1955b; Fredeen and Plank, 1963; Fredeen *et al.*, 1964).

V. HERITABILITY

The concept of heritability concerns the relative importance of

heredity and of environment as they influence the observed variations in a trait. Since the additive genetic fraction of the variance is the chief cause of resemblance between relatives and contributes to permanent genetic change in a population, the term "heritability" is generally accepted in its limited sense as being the portion of the total phenotypic variance which is due to additive gene action.

Since the heritability value depends on the magnitude of all the components of the variance, it is important to realize that the estimates are based on the variation in a particular trait in a specified population, at the time and under the conditions prevailing when the estimate was made.

Estimating heritabilities of characteristics is very useful in choosing an efficient breeding system. When the estimates of heritability of a character are high, the correlation between the phenotype and the genotype of the individual is high. In other words, the trait is highly heritable. Selection on the basis of the individual's own performance should be effective. On the other hand, if the estimate is low, the variation is mainly environmental and the breeding plan should put less emphasis on mass selection, and more upon pedigree, sib test, and progeny test.

Heritability estimates all depend upon the degree of resemblance between relatives. Estimation may be within parent-offspring, full sib, half sib, or other relationships.

Definitions and methods of estimating heritability were discussed by Lush (1940). In his early work (1936) of Danish progeny testing, he obtained reliable estimates of heritabilities in the Danish Landrace by averaging the maximum estimate of three methods of computation (paternal and maternal half sib and parent-offspring relationships). Dickerson (1947) in a selection experiment indicated that aside from the controlled selection experiment,

the regression of progeny performance on the mean performance of the two parents was probably subject to less bias than other methods commonly used. Several methods and their accuracy of estimating heritability were discussed by Fredeen (1953). He indicated that the most reliable estimates of heritabilities were those obtained by assuming an average intra-herd relationship between dams equivalent to that of half sisters (paternal half sibs). The pre-test environment, epistasis, and inaccurate appraisal of the average intra-herd relationship among dams were thought to be important sources of bias in the estimation of heritability. Estimates of heritability by paternal half sib correlations were found to be fairly high for most characters by other workers (Johansson and Korkman, 1951; Jonsson, 1957; Duckworth et al. 1961), when compared with the results of Fredeen (1953). Since the estimates from the dam component of variance might possibly contain maternal effects and sex linkage, these might overestimate tbe heritability (Dickerson, 1947; Duckworth et al. 1961). Duckworth et al. (1961) suggested that the heritability derived from the sire component gave the most accurate estimate because maternal effects were removed.

Estimates of heritability as reported by different workers fall in a large range. This may indicate that in addition to the difference in structure of the population, breed differences are important in estimation. The differences in methods employed are also to be considered. Estimates of heritability reported for some traits in R.O.P. programs of swine are summarized in Table 1.

Table 1. Estimates of heritabilities (h^2) of some traits of swine

Trait	h^2	Reference
1. Age at slaughter	0.27	Stothart (1947)
	0.57	Johansson and Korkman (1951)
	0.55	Fredeen (1953)
	(0.46)*	
2. Feed efficiency	0.08	Lush (1936)
	0.30	Fredeen (1953)
	0.45	Fredeen and Jonsson (1957)
	0.48	Jonsson and King (1962)
	0.73	Fredeen and Jonsson (1957)
	(0.41)	
3. Length	0.40	Fredeen (1953)
	0.42	Stothart (1947)
	0.45	Jonsson and King (1962)
	0.48	Fredeen and Jonsson (1957)
	0.49	Fredeen and Jonsson (1957)
	0.54	Lush (1936)
	0.62	Johansson and Korkman (1951)
	(0.49)	
4. Backfat thickness	0.37	Stothart (1947)
	0.38	Fredeen (1953)
	0.47	Lush (1936)
	0.47	Jonsson and King (1963)
	0.52	Johansson and Korkman (1951)
	0.52	Fredeen and Jonsson (1957)
	0.58	Fredeen and Jonsson (1957)
	(0.47)	
5. Loin area	0.16	Stothart (1947)
	0.66	Fredeen (1953)
	(0.41)	

*average of all the estimates for each trait

ORIGIN OF DATA

The R.O.P. records of Lacombe pigs from 1672 litters tested between 1958 - 1965 were used in this study. The traits chosen for study were:

(1) Age on test: age when the pigs averaged 50 lb. and were started on test.

(2) Age at slaughter: calculated from the day of birth to the day of shipping for slaughter, adjusted to a standard carcass weight of 155 lb.

(3) Days on test: difference between age on test and age at slaughter.

(4) Feed efficiency: since 1962, the total amount of feed used by the group during the test period divided by the live weight gain of the test group during the test period. Until 1963, live weight gain was obtained by the following formula: Live weight gain = 4/3 carcass wt. - live weight on test.

(5) Carcass length: measured to the nearest tenth of an inch from the outside of the first rib to the inner edge of the aitch bone.

(6) Shoulder fat: measured to nearest tenth of an inch at the point of maximum depth over the loin.

(7) Loin fat: measured to nearest tenth of an inch at the point of maximum depth over the loin.

(8) Total backfat: sum of the two backfat measurements (6) and (7).

(9) Loin area: The loin area was obtained by planimeter measurement of a tracing of the outline of the cross section of m. longissimus dorsi muscle at the last thoracic vertebrae.

(10) Loin/fat ratio: Ratio between the measurements of loin area (9) and total backfat (8).

Since the correlations were to be made between the progeny and the full sibs of each parent and between progeny and the average of the parental full sib records, no half sib records were used in this study.

Records of repeat testings of dams were used if the sow was mated to a different boar. But, if the sow was mated to the same boar, only the test with feed record was chosen. If neither test had a feed record, the earlier test was used unless two or fewer pigs were tested.

Present swine progeny testing results are reported on a litter average basis. In the foregoing review, sex differences did exist. Males were shown to be higher in growth rate but females superior in carcass merit. If all were four-pig-litters, evenly balanced for sex, any sex bias would be removed. But in the data actually reported, the litters were not always balanced for sex. Moreover, during the period of testing, there were cases where one pig died or was discarded for unthriftness and sometimes only three pigs or less had been sent to the slaughter plant. Therefore, the litter average was based on less than four pigs. Hence, there remained some variations from sex differences which were corrected before performing certain analyses. Any analysis of uncorrected data are so labelled. Uncorrected data were used for some analyses because these were the data available to the breeders. Litters not evenly balanced for sex were corrected for the average sex difference in age at slaughter, shoulder fat, loin fat and loin area in the manner shown in Table 2.

Since neither parent, one parent, or both parents were reared in the same herd with the offspring, five different classes were obtained for herd comparison. In class I. the progeny, sire and dam were reared in the same herd, that is, they had more or less the same environmental

Table 2. Sex corrections for unbalanced test litters

Number tested	4 pigs				3 pigs				2 pigs		1 pig	
Males (M) Females (F)	4M OF	3M 1F	1M 3F	OM 4F	3M OF	2M 1F	1M 2F	OM 3F	2M OF	OM 2F	OM 1F	1M OF
Age at slaughter (days)	+2	+1	-1	-2	+2	+0.67	-0.67	-2	+2	-2	+2	-2
Carcass length (in.)	+0.18	+0.09	-0.09	-0.18	+0.18	+0.06	-0.06	-0.18	+0.18	-0.18	+0.18	-0.18
Shoulder fat (in.)	-0.06	-0.03	+0.03	+0.06	-0.06	-0.02	+0.02	+0.06	-0.06	+0.06	-0.06	+0.06
Loin fat (in.)	-0.06	-0.03	+0.03	+0.06	-0.06	-0.02	+0.02	+0.06	-0.06	+0.06	-0.06	+0.06
Loin area (sq. in.)	+0.24	+0.12	-0.12	-0.24	+0.24	+0.08	-0.08	-0.24	+0.24	-0.24	-0.24	+0.24

Obtained from Livestock Research Office, Lacombe Expt. Station

background. There were 404 matings in class I.

Class II was made up of 20 matings in which progeny and sire, but not the dam, were produced in the same herd.

Class III involved 753 matings in which only progeny and dam were reared in the same herd.

In class IV, only sire and dam were from the same herd. There were 309 matings in this class.

In class V, 186 matings were involved in which neither the sire, dam nor the progeny were reared in the same herd.

The next step in organizing the data was to take the location of test (home or station) into consideration. Eighteen subclasses were obtained within each class of herd comparison (Table 3). Different locations of test of progeny, sire's sibs, and dam's sibs gave eight possible combinations of subclasses within each class of herd comparison (1st - 8th subclasses). But in some matings, only one parent's sibs had been tested. The location of test of the progeny and of one or the other parental sibs made up the other eight subclasses (9th - 16th subclasses). The last two subclasses (17th - 18th subclasses) included all the matings in which no sib records of either parent were available. The last two subclasses could not be used for correlation analysis.

The number of matings of each subclass within each herd comparison class are summarized in Table 3.

Table 3. Number of matings by herd comparison and location of tests

Herd Comparison	1 HHH*	2 HHS	3 HSH	4 HSS	5 SHH	6 SHS	7 SSH	8 SSS	9 HH-	10 HS-	11 H-H	12 H-S	13 SH-	14 SS-	15 S-H	16 S-S	17 H--	18 S--	Total
Class** I	78	1	2	5	5	4	4	30	58	6	31	8	5	11	4	16	104	32	404
Class II	0	1	1	0	2	0	1	2	3	0	0	2	0	4	1	0	3	0	20
Class III	18	35	12	32	31	58	25	62	29	26	19	50	53	54	33	131	31	54	735
Class IV	1	0	3	5	2	1	1	7	4	6	4	3	5	11	3	10	74	169	309
Class V	4	6	4	9	8	4	12	16	5	12	3	7	11	12	8	17	17	31	186

H=Home testing
S=Station testing
-=Without sib records

*The first location of test from the left is for the progeny, followed by the location of test of the sire's sibs and then the dam's sibs.

**See text P.25 for explanation of "class".

STATISTICAL PROCEDURES

The main statistical computations were preformed by an IBM 7040 electronic computer at the University of Alberta.

The program consisted of two decks. Deck 1 generated a frequency table (Table 3) on the basis of the herd comparisons and the subclasses defined by location of test. The program allowed for five herd comparison codes and eighteen subclasses of location of test. The program also made sex corrections (Table 2) of the data given on the basis of the number of males and females tested.

Two types of data cards were used. On card 1, registration number of the sire and the dam, date and location of test and the progeny performance were punched. On card 2, the registration numbers of sire, dam, sire's parents and dam's parents were punched (see Appendix B).

The program matched card 2 with card 1 and recorded on magnetic tape the progeny record, the sib records of sire and dam, herd code, and herd comparison class for each card 2.

Deck 2 read this information from the tape, and calculated the total fat and loin/fat ratios. It also calculated the mid-parent means where both parents had tested sibs.

The program then calculated the sum of all traits in each subclass. It then combined these subclasses and calculated the mean of progeny, mean of sire, dam or mid-parent mean (whichever was applicable), the sums of squares, corrected sums of squares, sums of products, corrected sums of products, and the correlation coefficients for each trait. The computations were checked for accuracy by desk calculator for one subclass.

The regression coefficients of progeny performance on parental sibs

were calculated with corrected sums of squares and sums of products obtained from the computer. Heritabilities were estimated by regression of progeny on parental sibs. Standard errors of estimates were calculated for regressions and heritabilities and significance of regression coefficients tested by the "t" test (Steel and Torrie, 1960).

All the averages of years, provinces, home testing, station testing, sire's sibs, and dam's sibs were also calculated by the computer.

The "t" test was used to test for significance of differences between the means (Steel and Torrie, 1960).

RESULTS AND DISCUSSION

I. EVIDENCE FOR GENETIC IMPROVEMENT AND SELECTION

A. Trends

In this study, one of the important phases was to consider the trends in performance that occurred from 1959 to 1964. The yearly averages of the performance traits of R.O.P. testing at home and station are given in Table 4 and Figures 1 - 9. No consistent annual changes were apparent for most of the traits. The reason for the apparent upward trend in loin area at station testing for the last three years is not apparent.

In studies of Yorkshire swine under the Canadian Advanced Registry Policy, Stothart (1947) and Fredeen (1953) found that no apparent improvement had been achieved. It was assumed that no consistent selection had been practised (Fredeen, 1953). No evidence was shown, however, until 1964 when Fredeen found that the average R.O.P. score for sires and dams of Yorkshire pigs registered during 1959 to 1961 in Ontario was identical to the average for all the R.O.P. tests conducted in Ontario during this three year period. The same was true for age to slaughter and feed conversion.

It is possible that deteriorating environmental trends could have obscured genetic gain. In this present study, major environmental variations (years, provinces, and location of test) were examined and evidence of selection was sought.

Table 4. Yearly averages of testing performance during 1959-1964[1]

		N	Age on test (days)	Age at slaughter (days)	Days on test (days)	Feed efficiency (lb./100 lb. live gain)	Carcass length (in.)	Shoulder fat (in.)	Loin fat (in.)	Total fat (in.)	Loin area (sq.in.)
1959	H[2]	9	-	162	-	-	31.5	1.64	1.25	2.89	3.85
	S	20	64	160	96	353	31.3	1.72	1.31	3.03	3.90
1960	H	116	-	170	-	-	31.1	1.67	1.30	2.97	3.88
	S	157	70	169	98	345	31.3	1.69	1.31	3.00	3.87
1961	H	171	-	170	-	-	31.1	1.73	1.33	3.06	3.83
	S	218	72	168	96	347	31.2	1.71	1.32	3.03	3.83
1962	H	118	-	176	-	-	31.1	1.62	1.25	2.87	3.78
	S	214	72	168	96	343	31.2	1.70	1.30	3.00	3.87
1963	H	114	-	174	-	-	31.1	1.63	1.25	2.88	3.71
	S	135	70	164	94	343	31.3	1.72	1.31	3.03	3.94
1964	H	157	-	171	-	-	31.1	1.70	1.31	3.01	3.81
	S	136	70	167	97	349	31.1	1.71	1.27	2.98	4.05
Total	H	685	-	171	-	-	31.2	1.67	1.28	2.95	3.81*
	S	880	70	166	96	347	31.2	1.71	1.30	3.01	3.91

Not corrected for sex differences

[1] Test records for 1958 and 1965 were not used because they were too few in number

[2] H=home testing; S=station testing

* = $P < 0.05$

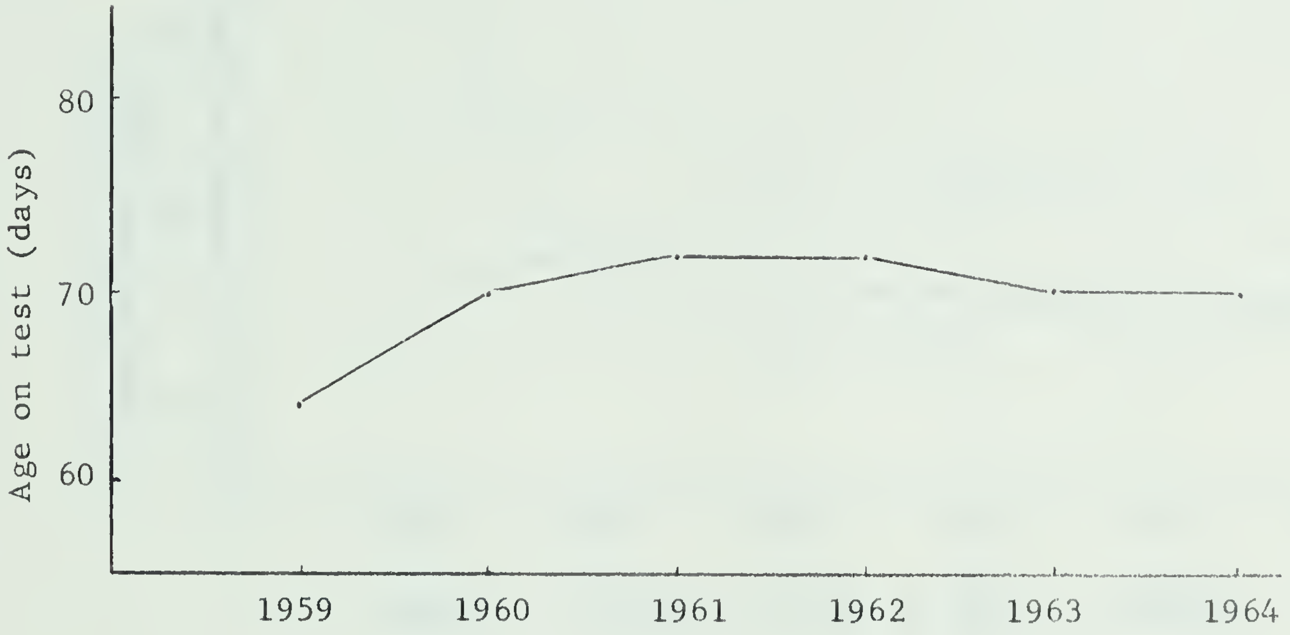

Figure 1. Trends in age on test at stations.

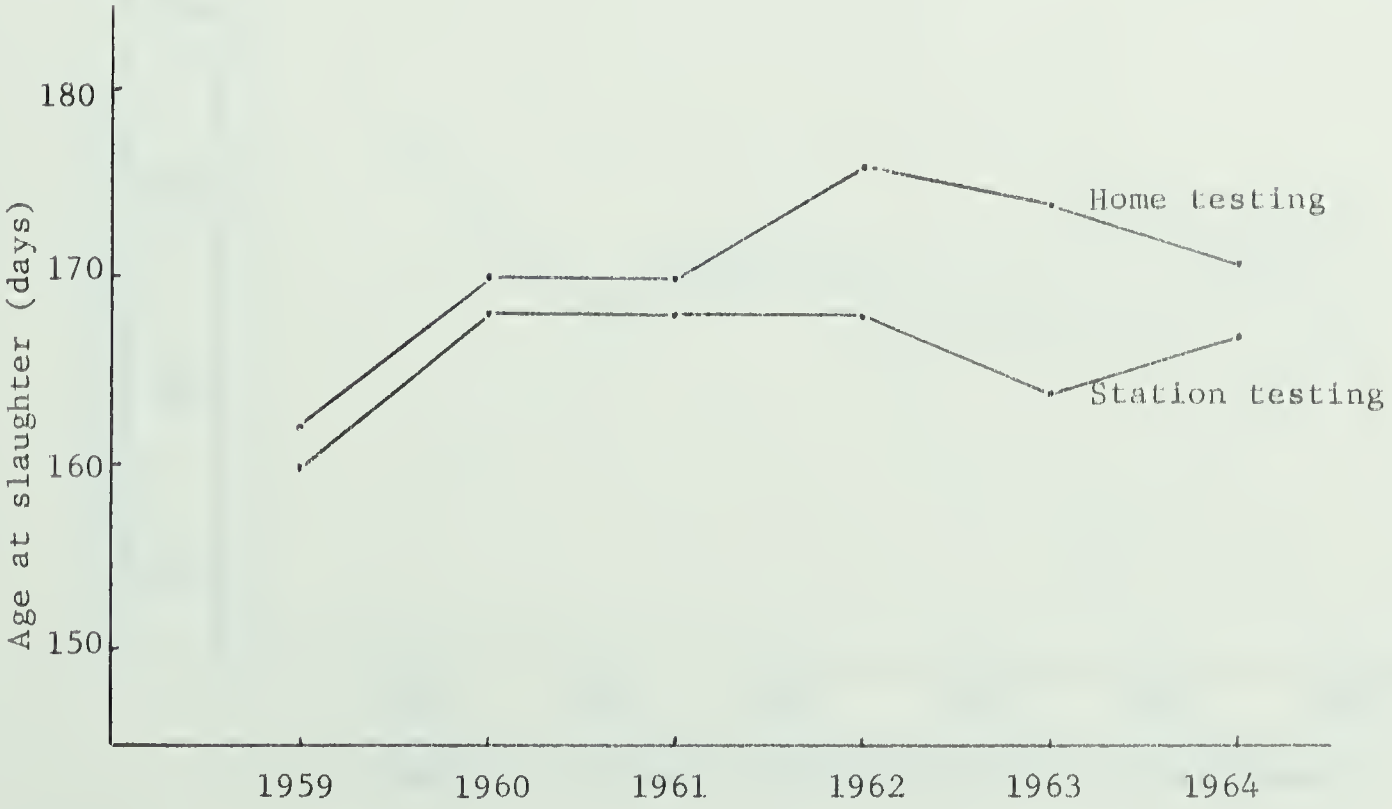

Figure 2. Trends in age at slaughter. (all tests)

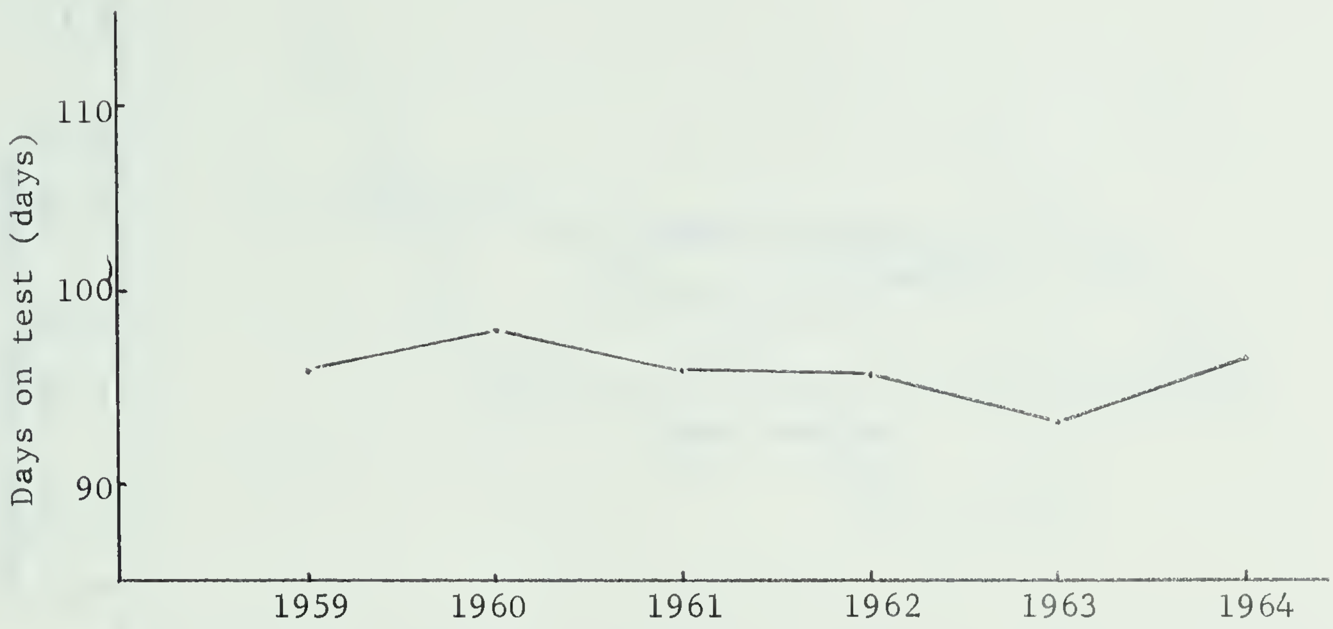

Figure 3. Trends in days on test at stations.

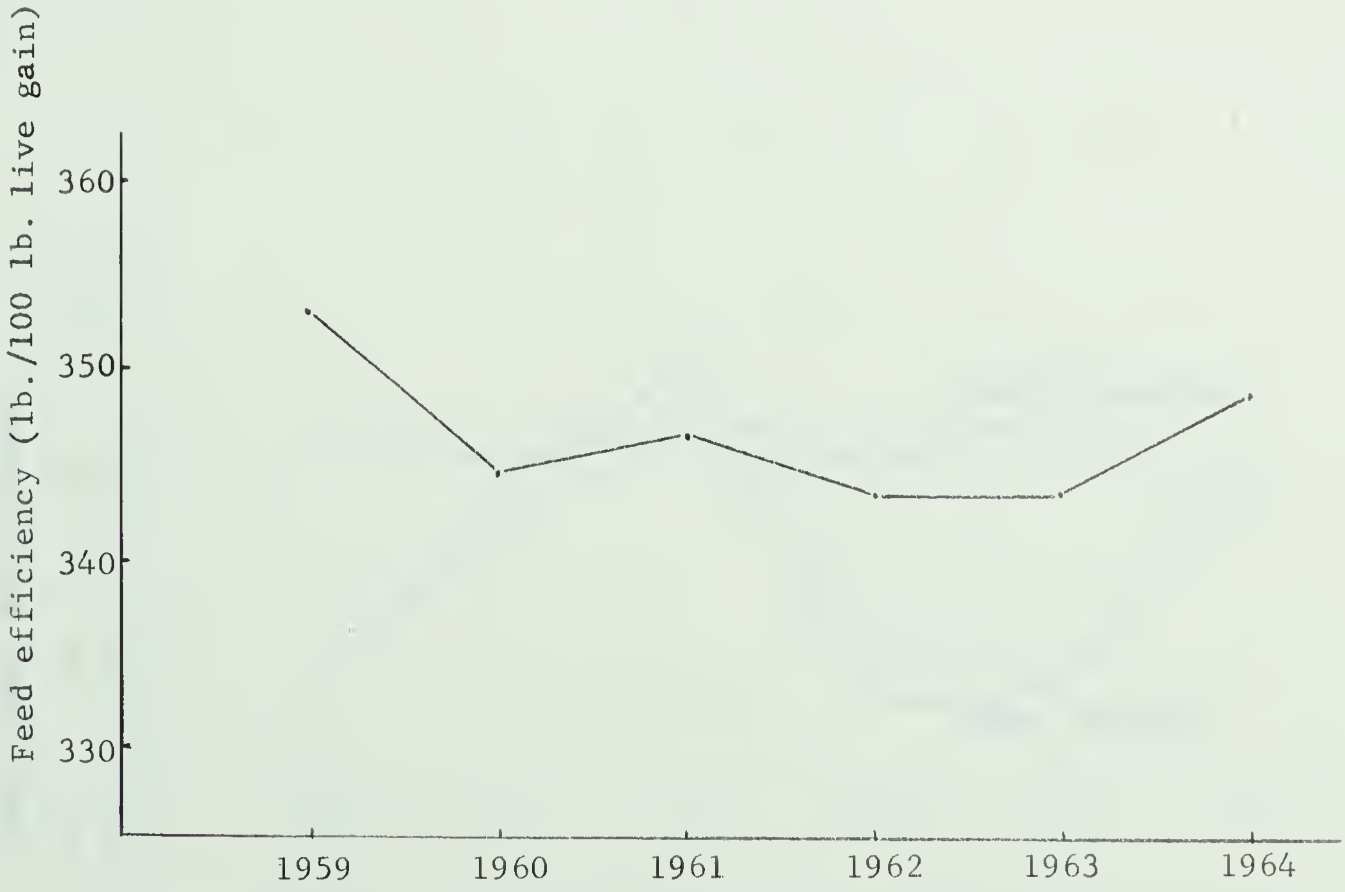

Figure 4. Trends in feed efficiency at stations.

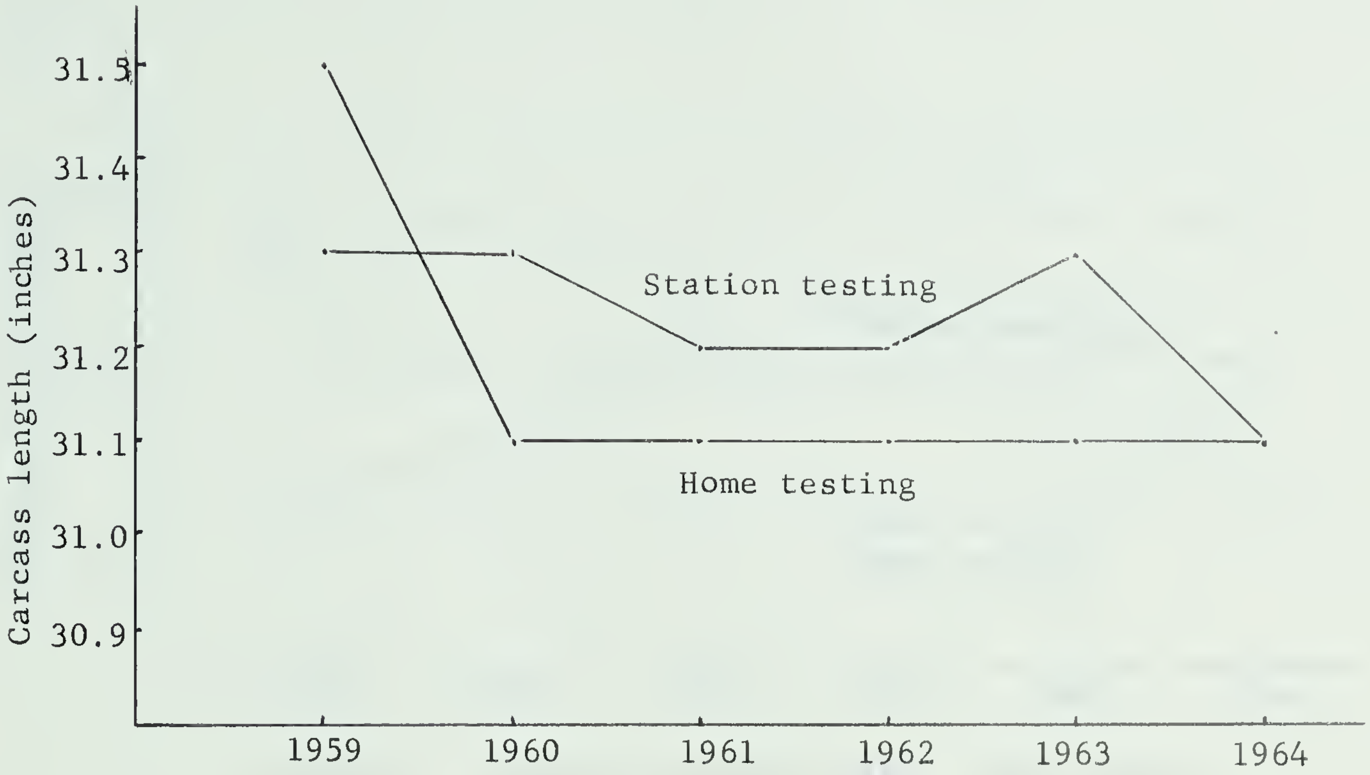

Figure 5. Trends in carcass length.(all tests)

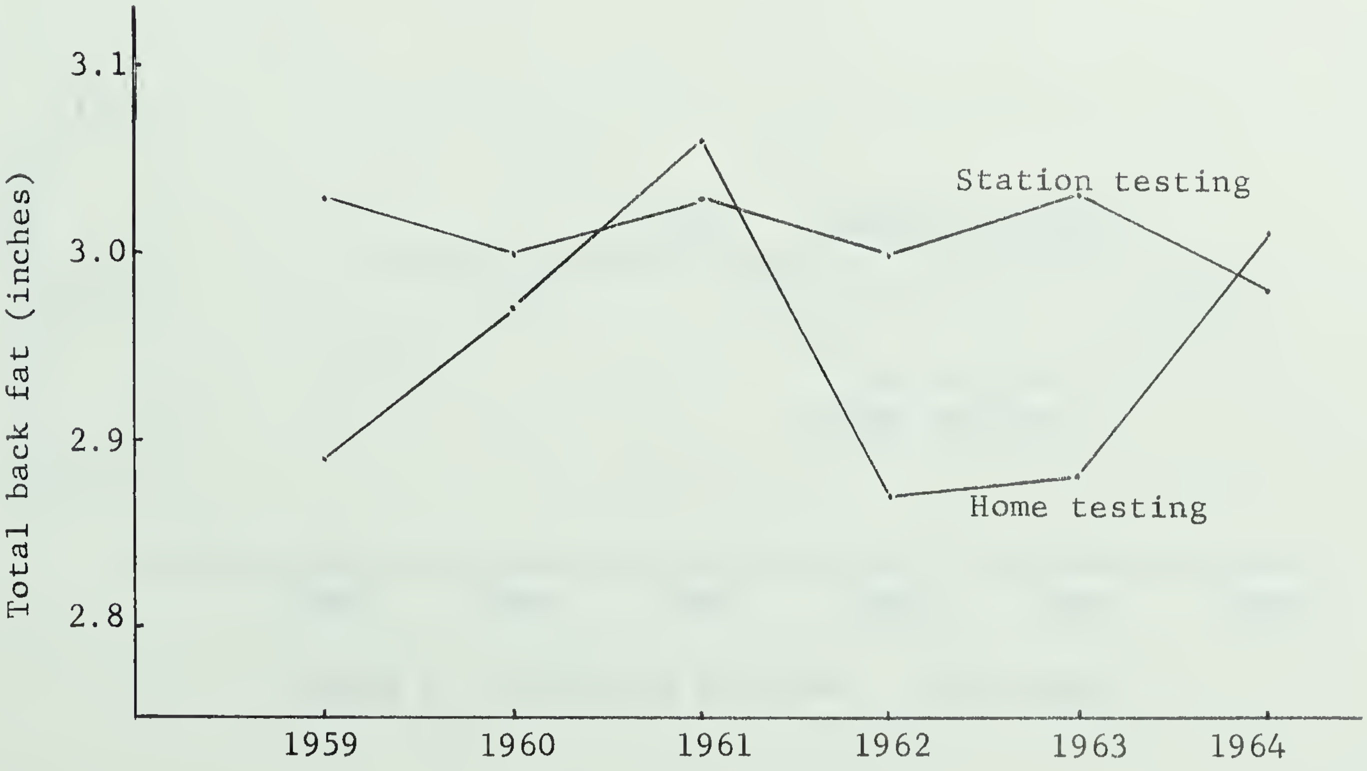

Figure 6. Trends in total backfat.(all tests)

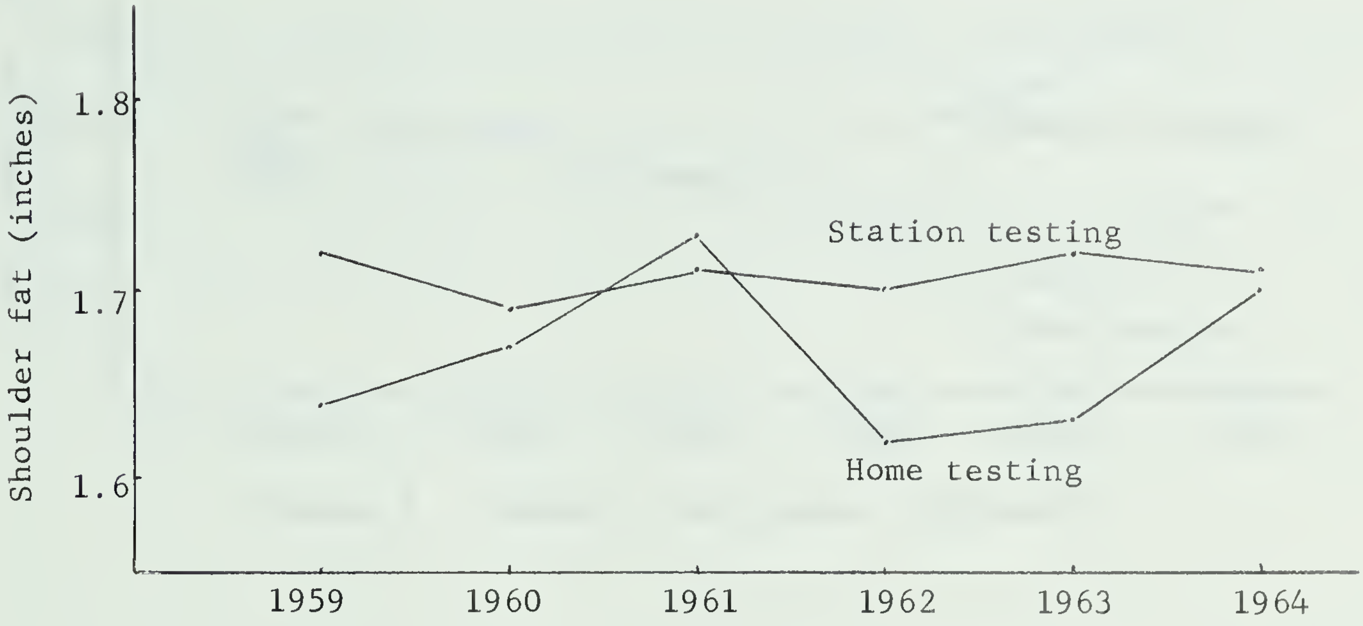

Figure 7. Trends in shoulder fat. (all tests)

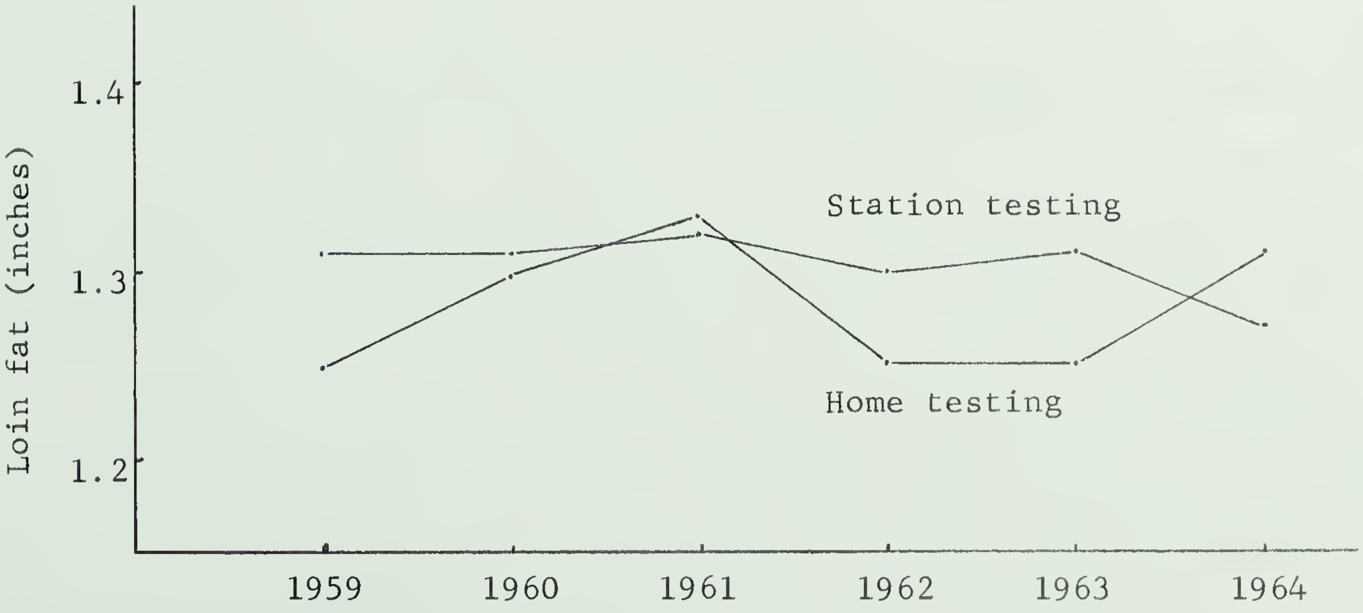

Figure 8. Trends in loin fat. (all tests)

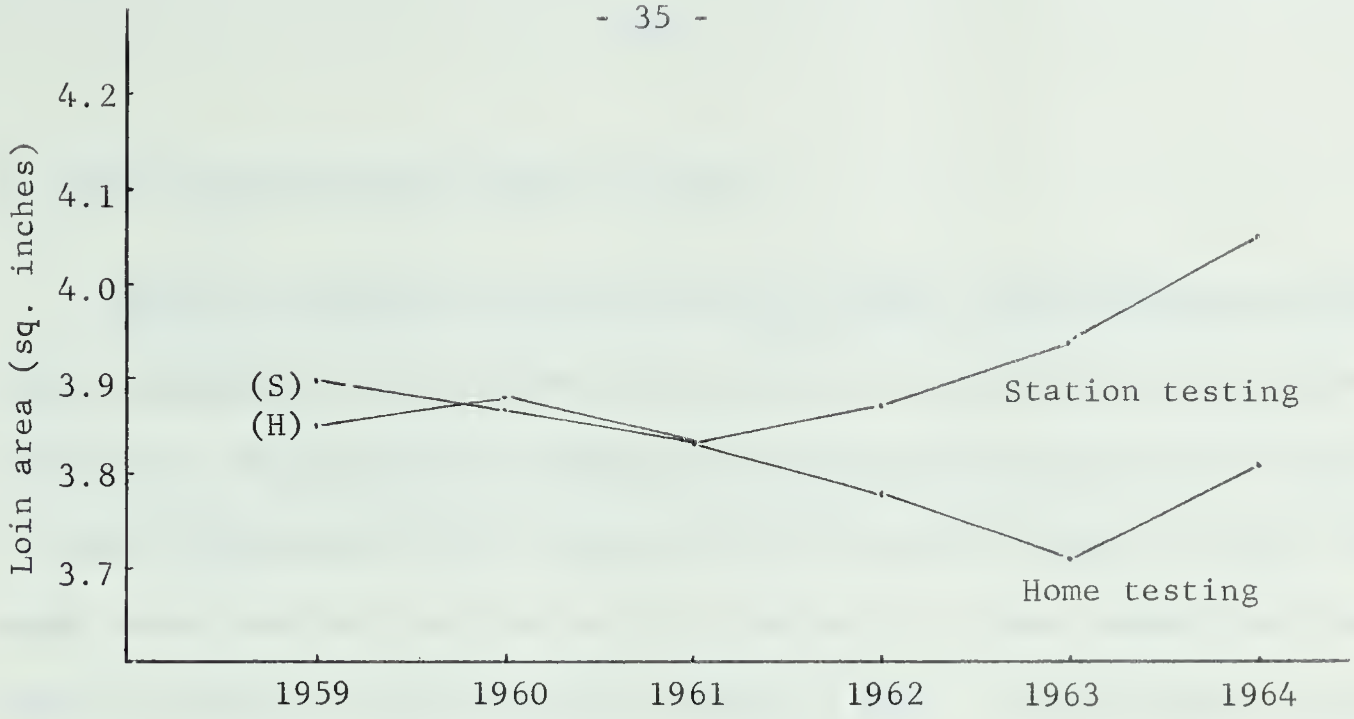

Figure 9. Trends in loin area. (all tests)

B. Home testing versus station testing

With the exception of loin area ($P < 0.05$), the differences in performance between home and station tests were not statistically significant (Table 4). The significant difference in loin area was due almost entirely to large differences which occurred in 1962 and 1963 when an upward trend began among station tests while loin area size in home tested pigs declined before returning to the six year average in 1964. These changes in loin area size coincided with increases in age at slaughter and decreases in shoulder and loin fat among home tested pigs during 1962 and 1963. The increased loin area in station tests was not accompanied by substantial changes in other traits. The reasons for the changes in loin area are not readily apparent.

It should be noted that the numbers of litters tested at home and station in each year and the yearly provincial averages varied among provinces (Table 5). Manitoba had the lowest age at slaughter but larger loin area while Ontario had the highest age at slaughter and Alberta the smallest loin eye area. Variations in distribution of tested litters each year among provinces and provincial differences caused by different management and environmental conditions could influence the annual means.

However, the apparent consistency of performance within provinces, and with no great shift in proportion of pigs tested among provinces,would indicate that provincial effects were not a major factor in obscuring genetic gain during 1959 - 1964.

Table 5. Provincial averages by years

Province	Year	N	Age on test (days)	Age at slaughter (days)	Days on test (days)	Feed efficiency (lb./100 lb. live gain)	Carcass length (in.)	Shoulder fat (in.)	Loin fat (in.)	Loin area (sq. in.)
Alberta	1959	13	63	158	92	351	31.5	1.74	1.33	3.71
	1960	143	71	168	97	336	31.1	1.70	1.31	3.84
	1961	191	74	169	93	345	31.1	1.78	1.36	3.82
	1962	108	75	175	97	348	31.3	1.72	1.29	3.78
	1963	109	72	165	92	339	31.2	1.71	1.31	3.76
	1964	138	74	169	98	358	31.0	1.73	1.33	3.80
Saskatch-ewan	1959	3	70	166	96	356	31.3	1.59	1.33	4.01
	1960	31	78	179	100	355	31.4	1.65	1.32	3.99
	1961	42	71	170	100	356	31.3	1.63	1.26	3.75
	1962	74	73	171	96	348	31.2	1.65	1.31	3.72
	1963	28	73	173	94	340	30.9	1.68	1.33	3.72
	1964	24	72	168	96	342	31.0	1.70	1.37	3.81
Ontario	1959	4	57	172	121	383	31.3	1.59	1.20	4.03
	1960	49	70	175	107	371	30.9	1.69	1.30	3.74
	1961	63	70	172	103	355	31.2	1.67	1.30	3.71
	1962	63	73	176	106	355	31.0	1.60	1.25	3.80
	1963	79	70	175	98	348	31.0	1.64	1.23	3.81
	1964	80	69	174	103	349	31.2	1.67	1.22	3.89
Manitoba	1959	9	61	157	95	346	31.2	1.71	1.28	4.00
	1960	41	78	161	91	329	31.6	1.64	1.30	4.04
	1961	84	69	165	93	336	31.2	1.69	1.32	3.83
	1962	79	66	162	91	333	31.2	1.67	1.27	4.00
	1963	29	66	160	92	350	31.9	1.66	1.23	4.29
	1964	38	65	158	91	340	31.1	1.66	1.23	4.29
British Columbia	1959	no tests		-	-	-	-	-	-	-
	1960	3	77	165	88	324	30.8	1.68	1.36	3.94
	1961	3	86	184	107	372	30.8	1.64	1.41	4.15
	1962	8	75	168	94	332	30.7	1.93	1.47	3.93
	1963	3	79	162	82	337	31.5	1.92	1.56	3.90
	1964	11	74	172	90	351	31.2	1.71	1.36	4.29

Not corrected for sex differences

C. The use of R.O.P. records

The number of litters tested in each year during 1959 to 1964 is given in Table 6. Test records for 1958 and 1965 were used only for correlation and regression analysis because they were too few in number to show meaningful yearly comparisons.

Table 6. Number of litters tested during 1959 - 1964

Year	Home	Station	Total
1959	9	20	29
1960	116	157	273
1961	171	218	389
1962	118	214	332
1963	114	135	249
1964	157	136	293
Total	685	880	1565

The reason for the decrease of litters tested during the last three years might be that either the importance of the sib testing and progeny testing was not realized by the breeders or that the procedures and regulations reduced the feasibility and acceptability of the testing. Tests are cancelled simply because the breeder is unwilling or unable to take the required time from other responsibilities to nominate litters for testing or transport the pigs to the test station. Some breeders are unwilling to sacrifice pigs for test when demand for breeding stock is high. It is also possible that some of the boars and sows were eligible for registration with no test required (see Appendix A).

In this study, in about half of the matings, the sires and dams had sib records (Table 7).

Table 7. Proportion of the matings in which sires and dams with or without sib records were used for breeding*

	Sires			Dams		
	Same herd	Diff. herd	Total	Same herd	Diff. herd	Total
With sib records	233 (52%)**	584 (47%)	807 (48%)	694 (60%)	148 (29%)	842 (51%)
No sib records	201 (48%)	664 (53%)	865 (52%)	463 (40%)	367 (71%)	830 (49%)
Total	424 26%	1298 74%	1672 100%	1157 69%	515 31%	1692 100%

*Combined subclasses from Table 3.
**Percentage of column total.

There was an indication that when breeders replaced boars and gilts from within their own herd, more tested animals were retained for breeding than when selection was from outside the herd. This was especially true for female selection since in the matings of dams selected from within the herd 60% had sib records, but in matings of dams selected from outside the herd only 29% had sib records. Of matings of sires selected from within the herd 52% had sib records as compared to 47% when the sire was selected from outside the herd.

In only 31% of the matings the dams were chosen from outside the herd but in 74% of the matings the sires were from outside the herd. The desirability of making selections from within the herd is to improve the accuracy of selection by limiting the extent to which environmental differences obscure genetic differences. Under some circumstances, a breeder might have a better opportunity to improve his stock by introducing new and superior genes to his gene

collection. In such cases, selection from outside the herds is thought to be desirable. It should be noted that comparisons between herds are not considered reliable unless pigs have been tested under the same conditions. Although R.O.P. test station policy was established for such a purpose, effects of environment are still involved.

Further analysis showed that the animals were not randomly mated to tested or untested mates. There was a tendency for tested animals to be mated to tested mates and untested to untested animals (Table 8).

Table 8. Expected and observed numbers and proportion of matings from tested and untested parents

		Sire's sibs			
		Tested (48%)		Untested (52%)	
		Expected**	Observed	Expected	Observed
Dam's sibs	Tested (51%)	410 (24.5%)	492 (29.5%)	442 (26.5%)	315 (18.8%)
	Untested (49%)	392 (23.5%)	350 (20.9%)	426 (25.5%)	515 (30.8%)

$X^2 = 76.67$ $P < 0.01$

**If mating random with respect to the sib testing of parents.

D. Comparisons between parental sibs and progeny averages

To examine for evidence of selection, the parental sib and progeny performance were averaged separately. The sex corrected differences between progeny performance and the performance of the sire's sibs, dam's sibs and the average of the parental sibs are given in Table 9. The performance of the sire's sibs and dam's sibs included the sires and dams from the matings in which one or both of the parents had been sib tested

but the performance of average parental sibs was of course obtained by averaging the sires and dams from only those matings in which both parents were tested.

Table 9. Comparison of testing performance of progeny with sire's sibs and dam's sibs

Trait	Progeny mean minus the mean of Average parental sibs (n=465/105)*	 Total sire's sibs (n=807/249)	 Total dam's sibs (n=842/355)
Age on test (days)	-1.38	-5.32	+0.63
Age at slaughter (days)	+2.26	+2.13	+2.56
Days on test (days)	+4.58	-0.23	+0.34
Feed efficiency (lb./100 lb. live gain)	+4.68	+5.80	-0.20
Carcass length (in.)	-0.04	-0.07	-0.02
Total fat (in.)	+0.07	+0.13	+0.04
Loin/fat	-0.10	-0.12	-0.03
Loin area (sq. in.)	-0.15	-0.20	-0.05

Corrected for sex differences.
*Larger number is for age at slaughter, carcass length, total fat, loin/fat ratio and loin area. The smaller number is for age on test, days on test, and feed efficiency since these traits include only station test.

As compared to the average of parental sibs, age at slaughter and days on test were greater in the progeny while age on test was lower. There was 4.68 lb. more feed required per 100 lb. live gain in the progeny. Carcass length and loin area were lower but thicker backfat was carried on progeny carcasses. The generally superior performance of the parental sibs, would indicate that selection had been practised. By looking at the greater differences in feed efficiency and in all the carcass traits between

progeny performance and the performance of sire's sibs, it appears that the sires were more intensively selected for these traits than were the dams.

Regression of progeny performance toward the population mean is due to environmental and other non-heritable variations that reduce accuracy of parental selection. Environmental conditions such as variations in litter size and management and transient gene interactions that are favorable to some animals but not to others contribute to such regression. These results show that the breeders have tended to reach for higher performance in making breeding stock selections.

Selection is assumed to have been practised, but no apparent improvement achieved during the period studied. How intensively the breeders actually did practise selection was then investigated.

In Table 10, sib averages of the sires and dams are given. In order to present the data in the terms in which they would appear to the breeders, these sib averages were not sex corrected nor weighted for number of progeny ultimately produced.

In comparing to the yearly averages, the sib averages of the sires were superior to yearly averages indicating that selection was being practised for most of the traits on sire's sibs. This is in agreement with the results obtained in Table 9.

If breeders actually were using the results of sib tests in selecting females for breeding, the dam's should also have averaged higher than their contemporaries as was found in sire's sibs , but there is no evidence to show any consistent superiority of the dam's sibs over the yearly averages. It is doubtful that the sib testing results have been effectively used as a basis of selection of dams.

The sib averages given in Table 11 differ from those in Table 10 in

Table 10. Averages of sire's sibs, dam's sibs, and the yearly averages

Year		N	Age on test (days)	Age at slaughter (days)	Days on test (days)	Feed efficiency (lb./100 lb. live gain)	Carcass length (in.)	Shoulder fat (in.)	Loin fat (in.)	Total fat (in.)	Loin area (sq.in.)
1959	Sire's sibs[1]	10	62	163	99	342	31.3	1.64	1.24	2.98	4.07
	Dam's sibs[2]	11	63	165	99	354	32.0	1.65	1.28	2.93	3.73
	Yearly av.	29	64	161	96	353	31.4	1.68	1.28	2.96	3.88
1960	Sire's sibs	59	68	167	99	341	31.3	1.66	1.28	2.94	4.09
	Dam's sibs	90	71	169	98	346	31.2	1.68	1.31	2.99	3.82
	Yearly av.	273	70	169	98	345	31.2	1.68	1.31	2.99	3.88
1961	Sire's sibs	53	71	167	99	348	31.1	1.69	1.28	2.97	3.88
	Dam's sibs	84	69	166	96	346	31.2	1.73	1.33	3.06	3.82
	Yearly av.	389	72	169	96	347	31.2	1.72	1.33	3.05	3.83
1962	Sire's sibs	25	68	167	99	342	31.1	1.52	1.14	2.66	4.07
	Dam's sibs	52	69	166	95	337	31.3	1.64	1.24	2.88	3.84
	Yearly av.	332	72	172	96	343	31.2	1.66	1.28	2.94	3.83
1963	Sire's sibs	18	68	162	92	342	31.2	1.65	1.28	2.93	4.08
	Dam's sibs	55	71	165	92	339	31.1	1.71	1.29	3.00	3.84
	Yearly av.	249	70	169	94	343	31.2	1.68	1.28	2.96	3.83
1964	Sire's sibs	3	62	164	98	334	30.8	1.63	1.10	2.73	4.00
	Dam's sibs	7	75	170	96	361	30.6	1.77	1.43	3.20	3.76
	Yearly av.	293	70	169	97	349	31.1	1.71	1.29	3.00	3.93
	S.D.		10.6	5.8	9.9	7.4	0.96	0.16	0.24	0.40	0.37

Not corrected for sex differences

[1] Average of sib tests of selected males

[2] Average of sib tests of selected females

that these sib averages were sex corrected and weighted for the numbers of litters tested from sib tested sires and tested dams. This further confirms that selection intensity was mainly placed on sire's sibs rather than on dam's sibs.

Since provincial differences did exist, and sires were more likely to be selected from outside the herd, one might wonder if these differences could be attributed to provincial differences due to a disproportionate number of sires originating in the better provinces. In tables 12 and 13, the provincial distribution of sire's sibs was in virtually the same pattern as total litters tested and annual registrations in different provinces during the period studied. This would indicate that apparent sire selection was not due to disproportionate sire contribution from provinces.

For further investigation, the average performance of progeny from dams with sib records was calculated within a herd to compare with the average performance of progeny from dams without sib records. These two averages and the dam's sibs for the seven largest herds from different provinces are given in Table 14. The lack of intensive selection of dams was further confirmed by the evidence that the performance of progeny from tested dams was not generally superior and in some cases was inferior to the performance of progeny from untested dams in seven of the largest herds.

Since the herd requirement for replacement gilts is generally greater than for boars, the selection potentiality of females is greatly reduced if two females and two males are sent for test.

All of the evidence considered has shown that sires were selected with sib tests superior to the average, especially for loin area but no performance improvement was found. One of the major considerations

Table 11. Sire's sib average and dam's sib average by years corrected for sex and weighted for number of progeny test

Year	Sib Averages	N	Age on test (days)	Age at slaughter (days)	Days on test (days)	Feed efficiency (lb./100 lb. live gain)	Carcass length (in.)	Shoulder fat (in.)	Loin fat (in.)	Total fat (in.)	Loin area (sq. in.)
1959	Sire's sibs	41	61	165	100	351	31.2	1.63	1.24	2.87	4.19
	Dam's sibs	83	60	161	99	360	31.3	1.69	1.28	2.97	3.90
	Yearly av.		64	161	96	353	31.4	1.68	1.28	2.96	3.88
1960	Sire's sibs	359	73	165	98	338	31.3	1.65	1.26	2.91	4.12
	Dam's sibs	294	72	168	98	344	31.2	1.67	1.29	2.96	3.98
	Yearly av.		70	169	98	345	31.2	1.68	1.31	2.99	3.88
1961	Sire's sibs	209	70	166	99	348	31.2	1.65	1.24	2.89	3.92
	Dam's sibs	234	69	164	96	342	31.3	1.70	1.28	2.98	3.92
	Yearly av.		72	169	96	347	31.2	1.72	1.33	3.05	3.83
1962	Sire's sibs	116	71	171	104	345	31.4	1.51	1.15	2.66	4.11
	Dam's sibs	115	73	167	94	330	31.2	1.63	1.24	2.87	3.97
	Yearly av.		72	172	96	343	31.2	1.66	1.28	2.94	3.83
1963	Sire's sibs	57	65	159	91	341	31.3	1.61	1.24	2.85	3.99
	Dam's sibs	107	72	165	93	338	31.3	1.69	1.28	2.97	3.84
	Yearly av.		70	169	94	343	31.2	1.68	1.28	2.96	3.83
1964	Sire's sibs	9	58	164	101	339	30.9	1.63	1.08	2.71	3.97
	Dam's sibs	9	74	171	96	355	30.8	1.78	1.40	3.18	3.79
	Yearly av.		70	169	97	349	31.3	1.71	1.29	3.00	3.93

Corrected for sex differences

Table 12. Distribution of sire's sibs by provinces and years

Year	Alta.	Man.	Sask.	Ont.	B.C.	Total
1959	3(30%)	3(30%)	1(10%)	3(30%)	-	10
1960	30(51%)	7(12%)	9(15%)	13(22%)	-	59
1961	28(53%)	4(8%)	7(13%)	14(26%)	-	53
1962	6(24%)	7(28%)	1(4%)	10(40%)	1(4%)	25
1963	12(67%)	3(17%)	1(6%)	2(11%)	-	18
1964	1(33%)	-	-	2(67%)	-	3
Total	80(48%)	24(14%)	19(11%)	44(26%)	1(1%)	168
Total litters tested	702(45%)	280(18%)	202(13%)	338(22%)	28(2%)	1550*

*This total litters tested differs from that in Table 4 because the litters tested in Nova Scotia, New Brunswick, and Prince Edward Island were not included.

Table 13. Annual registration for Lacombe swine

Year	Alta.	Man.	Sask.	Ont.	B.C.	Total
1959	26(40%)	24(37%)	2(3%)	13(20%)	-	65
1960	1112(68%)	158(10%)	176(11%)	172(10%)	11(1%)	1629
1961	957(48%)	312(16%)	291(14%)	418(21%)	13(1%)	1991
1962	660(34%)	307(16%)	317(16%)	651(33%)	21(1%)	1956
1963	1024(48%)	341(16%)	152(7%)	605(28%)	23(1%)	2145
1964	807(42%)	291(15%)	217(12%)	598(31%)	*	1913
Total	4586(47%)	1433(15%)	1155(12%)	2457(25%)	68(1%)	9699

*Number of pigs registered is included in Alberta

Table 14. Averages of dam's sibs (Ds); progeny with dam's sibs (Ps) and progeny without dam's sibs (Pn)

		N	Age on test (days)	Age at slaughter (days)	Days on test (days)	Feed efficiency (lb./100 lb. live gain)	Carcass length (in.)	Shoulder fat (in.)	Loin fat (in.)	Loin area (sq. in.)
Herd A	Ds	45	-	165	-	-	31.0	1.77	1.36	3.81
	Ps	140	-	164	-	-	31.0	1.76	1.36	3.86
	Pn	63	-	166	-	-	31.0	1.76	1.36	3.80
Herd B	Ds	7	78	167	86	322	31.0	1.72	1.28	3.92
	Ps	8	80	179	94	348	31.2	1.80	1.28	3.62
	Pn	30	73	170	90	348	30.8	1.75	1.30	3.84
Herd C	Ds	7	72	176	111	365	31.2	1.88	1.32	3.74
	Ps	15	67	180	112	380	30.9	1.79	1.25	3.69
	Pn	6	70	180	119	374	31.1	1.81	1.35	4.03
Herd D	Ds	6	70	173	101	350	30.9	1.62	1.26	4.06
	Ps	18	67	176	116	380	30.9	1.63	1.22	3.84
	Pn	2	61	175	115	351	31.1	1.64	1.29	4.09
Herd E	Ds	19	61	154	93	345	31.1	1.69	1.30	3.98
	Ps	42	60	152	92	337	31.1	1.67	1.27	4.07
	Pn	11	67	158	94	361	31.5	1.62	1.24	4.27
Herd F	Ds	5	63	156	89	331	30.9	1.80	1.41	3.79
	Ps	31	74	167	85	320	31.0	1.75	1.40	3.91
	Pn	2	72	167	93	320	30.9	1.72	1.40	3.83
Herd G	Ds	2	69	168	92	338	31.3	1.58	1.31	3.76
	Ps	4	73	166	89	345	31.2	1.66	1.37	3.41
	Pn	9	75	173	95	350	31.3	1.57	1.28	3.80

Not corrected for sex differences

that affects rate of progress is the generation interval since the shorter the generation interval when effective selection is practised the greater the genetic gain expected. However, the cost and inconvenience of testing may result in the continued retention of progeny tested boars. The generation interval would then be prolonged. The prolongation of the generation interval could be important in reducing the effects of selection and make progress difficult to detect during the relatively short period analysed. No study of generation interval was made.

Since the measurements in sib testing (also in progeny test) were not made on the pigs actually available for breeding, there is a significant probability that the remaining pigs actually used for breeding are inferior to the tested sibs due to sampling of pigs for test. The accuracy of selection based on sib performance could be reduced. Sampling effects will be discussed in more detail in subsequent sections.

II. RELATIONSHIPS BETWEEN PARENTAL SIBS AND PROGENY

A. Parental sibs and progeny correlations

Since parents can not have their own carcass quality evaluated directly (live pig carcass measurements have not been adopted in the R.O.P. program), there is no possibility of obtaining a direct parent-offspring correlation as can be done, for example, in dairy cattle where the correlation between production of daughters and dams can be studied. The correlations in this study could only be calculated between progeny and parental sibs. Since 515 litters were from matings with neither sire's nor dam's sibs records (subclasses 17 and 18 in Table 3), only 1157 litters were useful for correlation analysis.

In order to increase the sample size for a valid interpretation, some

of the subclasses were combined on the basis of the herd comparisons and location of test (home or station). The correlations were first calculated between progeny mean and the means of the parent's sibs for two main groups. The first group combined all the subclasses in which parental sibs and progeny were from the same herd. The second group included all the subclasses in which the parental sibs and progeny were reared in different herds. Each group was then subdivided into subgroups in which the parental sibs and progeny were tested either both under the same testing (both home or both station testing) or each under different testings. The correlations for each subgroup were computed between sire's sibs and progeny and between dam's sibs and progeny performance.

Correlations between progeny and average of the both parental sibs were made for the group combining all the subclasses in which both parents' sib records were available without regard to the herd comparison and location of test.

The performance traits for correlation study were age at slaughter, age on test, days on test, feed efficiency, carcass length, total fat, loin area and loin/fat ratio. Since home testing does not provide the data of days on test, age on test and feed efficiency, no correlations could be made for these traits when either progeny or parental sibs were home tested. Total fat and loin/fat ratio given here are not official R.O.P. measurements.

The correlation coefficients between progeny and parental sibs and average of the parental sibs under different conditions are given in Table 15.

Progeny and parental sibs were generally more highly correlated, particularly for age on test, when both were from the same herd than when from different herds. The reason is apparent that the parental sibs and

Table 15. Correlations between progeny and parental sibs

Conditions of correlations	d.f.+	Age on test	Age at slaughter	Days on test	Feed efficiency	Carcass length	Total fat	Loin/ fat	Loin area
1. Prog.-Sires:same herd	221/50	0.20	0.28**	0.70**	0.45**	0.17**	0.22**	0.24**	0.19**
a.Both home tested	139	-	0.09	-	-	0.10	0.24**	0.05	0.25**
b.Both station tested	50	0.20	0.46**	0.70**	0.45**	0.29**	0.05	0.40**	0.21
c.Sire:home;Prog.:station	14	-	-.26	-	-	-.01	-.62**	-.42	-.24
d.Sire:station;Prog.:home	12	-	0.13	-	-	0.26	-.33	0.69**	-.05
2.Prog.-Sires:diff. herd	582/198	0.17**	0.09*	0.10	-0.01	0.06	0.16**	0.01	-.05
a.Both home tested	100	-	0.13	-	-	0.19*	0.29**	-.02	-.26**
b.Both station tested	198	0.17*	0.10	0.10	-0.01	0.02	-.02	0.11	0.16*
c.Sire:home;Prog.:station	171	-	0.27**	-	-	0.14*	0.24**	0.13*	-.04
d.Sire:station;Prog.:home	107	-	-.13	-	-	0.12	0.14	-.10	-.08
3. Prog.-Dams:same herd	692/299	0.45**	0.23	0.77**	0.14*	0.06	0.22**	0.27**	0.19**
a.Both home tested	158	-	0.13	-	-	0.28**	0.47**	0.46**	0.15
b.Both station tested	299	0.45**	0.43**	0.77**	0.14**	-.02	0.15**	0.27**	0.29**
c.Dam:home;Prog.:station	100	-	0.06	-	-	0.12	0.06	0.16	0.09
d.Dam:station;Prog.:home	129	-	0.05	-	-	0.26**	0.14	0.11	0.18
4.Prog.-Dams:diff. herd	146/55	-.16	0.03	0.00	0.13	0.04	0.22**	0.208	0.21**
a.Both home tested	18	-	0.17	-	-	0.16	0.21	0.12	0.08
b.Both station tested	55	-.16	-.01	0.00	0.13	-.22	0.28*	0.39**	0.53**
c.Dam:home;Prog.:station	36	-	0.25	-	-	-.15	0.12	0.08	-.05
d.Dam:station;Prog.:home	31	-	-.18	-	-	0.13	0.21	0.20	0.23
5.Progeny and av. parental sibs	463/105	0.15	0.18**	0.10	0.39**	0.08	0.29**	0.20**	0.05
6.Prog. and total sire sibs	805/249	0.15*	0.13**	0.12	0.12	0.08**	0.20**	0.09**	0.00
7.Prog. and total dam sibs	840/355	0.12*	0.20**	0.17**	0.14**	0.05	0.22**	0.26**	0.20**

Corrected for sex differences

* = $P < 0.05$ ** = $P < 0.01$

+ The larger d.f. is for age at slaughter, carcass length, total fat, loin/fat ratio and loin area. The smaller d.f. is for age on test, days on test and feed efficiency since these traits are not measured at home testing.

progeny would have been reared under similar environmental conditions.

Higher correlations between progeny and parental sibs in backfat measurement were found in most of the cases when both were home tested. On the other hand, correlations for age at slaughter were found higher for station testing when progeny and parental sibs were from the same herd. However, the considerably inconsistent results for other traits studied makes it difficult to draw a general conclusion as to which test, home or station, provides the better estimate of progeny performance.

A surprising result was the presence of certain negative correlation coefficients, but most of these negative values were not significant with the exception of that for total fat in group 1 (c) and loin area in 2 (a). If these traits are heritable, one would expect to have at least a slight positive correlation between progeny and parental sibs. Large sampling errors might be expected in groups 1 (c) and 1 (d), however. A closer inspection of these two groups revealed that a few sires contributed a large proportion of the matings and had a great influence on the sire's sib average. For example, a sire with a high sib average produced progeny of lower performance than a sire with a lower sib average. Such lead to the negative correlations between sire's sibs and progeny performance. This could also be applicable to group 2 (a) although the sample size was much larger.

When the correlations were calculated between the average of parental sibs, total sire's sibs, total dam's sibs and the progeny, ignoring the herd comparison and location of test, most of the correlations were positive and statistically significant but were generally too low to have any important predictive value. The highest correlation between progeny and parental sibs accounted for only 15% of the total variance of that trait.

Since the correlations estimated were generally low, test performance was not a good predictor of full sib breeding value. This would possibly be due to certain practices of litter sampling and selection. There is a probability that the pigs sent for test are superior to the remaining pigs in the litter. In randomly choosing a sample of four pigs (two males and two females) for test from a litter of eight piglets consisting of four males and four females, there is a probability of 1/6 of choosing the best male pigs for any single trait for test and slaughter. The chances that the sib test performance will deviate from the performance of the remaining pigs in the litter might be great enough to bias the estimation of correlations between progeny and sib performance. This is especially true since sires were selected from only 168 of the 1565 tests,about 11% as shown in Table 10.

Chances of bias ould be increased (or decreased) if the pigs for test had been chosen in a non-random manner. Selection of pigs for test can usually be made only on weaning weight. This would somewhat bias the measurements of growth rate but would be expected to have only slight effects on carcass measurements because the carcass traits are not highly correlated with weaning weight (Blunn and Baker, 1947).

If deviations due to the sampling of test pigs do exist, the more intensive apparent selection of sire's sibs,especially for loin area which was the most intensively selected trait,may reflect the selection of sires from sib tests in which the better sibs were tested. This would (a) more seriously bias the sib test and (b) leave only inferior males for breeding. This would then explain the lower correlations generally found between progeny and sire sibs.

It is also noted that correlations between progeny and sire sibs were

significantly higher when both were from the same herd than when from different herds. If the sib test performance is the basis for outside herd selection of the sires, the breeders would more often have the opportunity to select males with biased sib tests because of the larger population from which to select the relatively few males which are required. Taken together with between-herd environmental differences the effects of the sampling of test pigs and of intensive selection of sire sibs from outside the herd could explain the zero correlation for loin area between progeny and sire's sibs.

Since no evidence of any intensive selection had been shown in dam's sibs, the sampling effects in biasing the progeny-sire's sib correlations would be expected to be less on progeny-dam's sib correlations.

B. Regression and heritability

Estimates of heritabilities were based on parental sibs and progeny relationship. As with the litters used for correlation, the data were corrected for sex differences. Simple regression coefficients of progeny on parental sibs were calculated. The regression coefficients, standard errors and "t" values are given in Table 16.

Most of the regression coefficients either approached or exceeded the 0.05 level of statistical signficance from zero except carcass length and days on test. Estimation of regressions could also have been biased by the sampling of test pigs and selection practice of sire sibs. This seems especially true for loin area as discussed in the previous section.

In these estimations of heritabilities, of necessity, the parental sib average was used instead of the parent's own performance. Also, the progeny average was used instead of individual values. The phenotypic

Table 16. Regression coefficients (b) of progeny on parental sibs, standard errors (s) and "t" values

Trait		Regression of progeny on						
		Sire's sibs		Dam's sibs		Total sire's sibs	Total dam's sibs	Average parental sibs
		Same herd	Diff. herd	Same herd	Diff. herd			
		221/50	582/198	692/299	146/55	805/249	840/355	463/105
Age on test	(b)	0.19	0.02	0.44	0.02	0.02	0.05	0.06
	(s)	0.138	0.009	0.045	0.018	0.010	0.019	0.045
	(t)	1.377	2.222*	9.778**	1.111	2.000*	2.632**	1.333
Age at slaughter	(b)	0.31	0.11	0.27	0.04	0.16	0.23	0.27
	(s)	0.071	0.045	0.044	0.033	0.041	0.040	0.023
	(t)	4.366**	2.444**	6.136**	1.212	3.902**	5.750**	11.739**
Days on test	(b)	0.49	0.48	0.31	0.00	0.48	0.24	0.67
	(s)	0.071	0.334	0.224	0.100	0.247	0.200	0.633
	(t)	6.901**	1.437	1.384	0.010	1.943	1.200	1.058
Feed efficiency	(b)	0.41	-0.01	0.09	0.07	0.12	0.09	0.23
	(s)	0.114	0.078	0.010	0.084	0.064	0.035	0.010
	(t)	3.596**	0.128	9.000**	0.833	1.875	2.571*	2.300*
Carcass length	(b)	0.17	0.16	0.14	-0.04	0.18	0.11	0.30
	(s)	0.064	0.100	0.084	0.090	0.075	0.074	0.173
	(t)	2.656**	1.600	1.667	0.444	2.400*	1.486	1.734
Total fat	(b)	0.23	0.18	0.27	0.24	0.24	0.27	0.46
	(s)	0.071	0.044	0.014	0.090	0.040	0.044	0.071
	(t)	3.239**	4.901**	19.286**	2.667**	6.000**	6.136**	6.479**
Loin/fat	(b)	0.22	0.01	0.29	0.21	0.09	0.27	0.29
	(s)	0.064	0.045	0.045	0.084	0.038	0.032	0.071
	(t)	3.438**	0.222	6.444**	2.500*	2.368*	8.438**	4.085**
Loin area	(b)	0.17	-0.01	0.18	0.19	0.00	0.19	0.07
	(s)	0.064	0.033	0.033	0.071	0.034	0.032	0.064
	(t)	2.656**	0.303	5.455**	2.676**	0.029	5.938**	1.094

* = $P < 0.05$ ** = $P < 0.01$

variance of the parents and progeny was thus somewhat reduced.

With this method of estimation, heritabilities are expected to be higher than estimates obtained on individual performance due to reduction of non-genetic variation. The heritability of sib average (h_s^2) can be expressed in terms of the heritability of individual values (h_i^2) by means of the following equation (see Falconer, 1960):

$$h_s^2 = \frac{rn}{1 + (n-1)\,t}\, h_i^2$$

in which,
n = number of full sibs
r = genetic relationship between full sibs
t = phenotypic correlation between full sibs

Minkema _et_ _al_. (1964) in a comparative study of the effectiveness of individual selection and sib selection showed that the heritability of sib average was a little higher than that of individual values.

For most of the traits in this present study, the heritabilities estimated were generally lower than previous estimates (see Tables 1 and 17). This indicates that the environmental variations were extremely large and a deviation in performance of tested pigs from remaining breeding stock due to sampling when choosing the test pigs could also have biased the estimates. All these variations have already been discussed as they might affect the estimations of correlations and regressions.

That the sire's sibs and progeny are less likely to be reared in the same herd than the dam's sibs and progeny might cause lower estimates of heritability based on sire's sibs when data from an entire breed is used. Since a sire is usually mated to several dams, the degrees of freedom for estimating the relationship between progeny and sire's sibs tend to be overestimated. The estimates based on progeny and dam's sibs would be more reliable.

An estimate of 0.06 for age on test reflects that the variation of this trait is subject to considerable management influence. An estimate of 0.27 for age at slaughter is identical with that obtained by Stothart (1947) by using the same method of estimation, but for the same trait 0.55 has been reported by Fredeen (1953) on paternal half sib correlation in the Yorkshire breed. No evidence of selection could be found. It was assumed that common pre-test environment would have increased the non-genetic likeness between half sibs. For the three estimates of days on test, the standard errors are high and heritability estimates should not be considered reliable although that from dam's sibs seems the most reasonable.

Table 17. Heritabilities estimated on progeny-parental sib regressions

Trait	Method of estimation					
	Regression of progeny on total sire's sibs		Regression of progeny on total dam's sibs		Regression of progeny on average of parental sibs	
	h^2	S.E.	h^2	S.E.	h^2	S.E.
Age on test	0.04	± 0.020	0.14	± 0.038	0.06	± 0.045
Age at slaughter	0.32	± 0.082	0.46	± 0.080	0.27	± 0.023
Days on test	0.96	± 0.494	0.48	± 0.400	0.67	± 0.633
Feed efficiency	0.24	± 0.128	0.18	± 0.070	0.23	± 0.100
Carcass length	0.36	± 0.150	0.22	± 0.148	0.30	± 0.173
Total fat	0.48	± 0.080	0.54	± 0.088	0.46	± 0.071
Loin/fat	0.18	± 0.076	0.54	± 0.064	0.29	± 0.071
Loin area	0.00	± 0.068	0.38	± 0.064	0.07	± 0.064

The present estimates of heritability for loin area (0.07), carcass length (0.30) and feed efficiency (0.23) are all lower than other estimates which average near 0.41 for loin area, 0.49 for carcass length and 0.41 for feed efficiency (Table 1). The low value for loin area is due to an estimate of zero from sire's sibs and probably related to the problems of bias in litter sampling and selection previously discussed.

SUMMARY AND GENERAL CONCLUSIONS

The records of 1672 litters tested from 1958 to 1965 under the Canadian Record of Performance Policy for Lacombe swine were taken for analysis.

No apparent improvement in any trait had been achieved during the period of study. The major environmental variations which might be important in obscuring possible genetic gain for the period studied were examined and evidence of selection was sought. Relationship between parental sibs and progeny by means of correlations, regressions and heritabilities were estimated.

No significant differences were found between performance in home testing and station testing except for loin area. Provincial differences by years did exist, but the considerable consistency of performance within provinces, and with no great shift in proportion of pigs tested among provinces, indicated that provincial effects were not a major factor in obscuring genetic gain.

Among test litters, 48% were by sib tested sires and 51% out of sib tested dams. The frequencies of matings in which both or neither of the parents were sib tested were higher than would have been expected under random mating. It was further indicated that in 74% of the matings the sires were selected from outside the herd in which their progeny were tested while in only 31% of the matings were the dams selected from outside the herd.

The generally superior performance of the parental sibs as compared to progeny indicated that selection had been practised especially on sire sibs. Further evidence by comparing the parental sib averages to their contemporaries confirmed this. By looking at the provincial distribution

of sire's sibs in comparison to proportions of registrations and litter tests, it was noted that apparent sire selection was not due to disproportionate sire contributions from the better provinces.

The yearly dam's sib averages were not superior to those of their contemporaries and the progeny of tested dams were not superior to those from untested dams all indicating that no apparent selection was made for dams with high testing sibs.

All the evidence considered showed that breeders had attempted to reach for higher performance in making sire selections. But no measureable trends of improvement were found.

Testing results have long been known to provide a basis for between herd comparisons. But between-herd environmental variations do exist, and since most of the sires were selected from outside the herds, between-herd environmental variations could result in inaccurate selection.

The great loss of potential breeding stock by sending a group of four pigs for test reduces the opportunities for intensive selection. Furthermore, testing the better pigs due to sampling in choosing the pigs for test, thus leaving inferior pigs for breeding, could occur frequently enough to have further reduced the accuracy of selection on sib performance. This would be especially true for sires selected from outside the herd.

The inconvenience and cost of sending pigs to testing stations could result in the retention of tested parents for longer periods of time in a herd, which would thus prolong the generation interval. The prolongation of the generation interval would reduce the rate of progress.

Correlations between progeny and parental sibs were estimated by herd comparison and location of test. No consistent results were evident to show which test, home or station, could provide the better estimate of

progeny performance. The correlations were generally higher when parental sibs and progeny were both from the same herd.

Most of the correlations estimated were statistically significant but were too low to be of good predictive value. Testing and slaughtering the better pigs due to sampling or choosing the better pigs for test could have left the inferior pigs for breeding. The effect of selecting the highest sire's sib averages, particularly from outside the herd, could have biased the progeny-sire's sib correlations resulting in a zero correlation for loin area and generally low correlations for other traits. Progeny-dam's sib correlations were not so seriously affected since no intensive selection was evident.

Heritabilities were estimated from progeny-parental sib regressions. This method of estimation differs from estimates obtained on individual values in that the use of sib averages tends to reduce the non-genetic variation and is expected to result in higher and more accurate heritability estimates. While the regressions in this study were mostly statistically significant, except carcass length and days on test, the resulting heritability estimates tended to be lower than in previous reports. This was due to the probable bias from the sampling of test pigs and large environmental variations between herds.

All the evidence from progeny-parental sib relationships studied (correlations, regressions, and heritabilities) indicate that selection in this R.O.P. program is not very promising. It seened that the breeders had selected loin area most intensively on sire's sibs, but the heritability estimated for this trait based on sire's sibs was zerio which would result in no return from selection.

If sib testing is the basis for selection, the accuracy of selection

is greatly reduced since the testing performance can not always be indicative of the merit of the remaining pigs in the litter due a probability of choosing the best pigs for test that is high enough to result in serious inaccuracies in selection of the remaining sibs. This is especially true for sire selection.

Failure to turn generations may also have contributed to the lack of apparent improvement. Although generation length was not determined in this study.

IMPLICATIONS

Similar results,that no apparent improvement could be measured in the Canadian R.O.P. program,were reported in Yorkshire swine by Stothart (1937) and Fredeen (1953; 1965b). No consistent selection was evident in Fredeen's studies (1953; 1965b), but in this study of Canadian Lacombes under selective registry, the practice of selection particularly on sire's sibs has been shown.

Selection on sib performance is thought to be inaccurate, however, due to bias in litter sampling and large environmental differences between herds. This was particularly true in sire selection because the majority originated outside the herd in which they were used. This might suggest that measurements on the individual pigs which will actually be available for breedingare necessary. To approach this, live pig backfat probing and individual feeding can be practised. The loss of potential breeding stock would also be eliminated. Progeny-parental sib relationships studied had indicated that selection within herds could be less biased by environmental variations and litter sampling. Because selection between herds is complicated by the large environmental differences, within-herd comparisons as a basis for selection seem essential.

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APPENDIX A

Rules for Registration of Lacombe Swine

The following shall be eligible for registration:

(a) An animal born in Canada whose sire and dam are registered in the Lacombe section of the General Stud and Herd Book or in the Canadian Lacombe Swine Herd Book, and

(b) which is certified to be representative of the breed as outlined in Description, to be free from disqualifications including black hair, ruptures, cryptochidism and hermaphroditism, to be sound and to have a minimum of 14 well-spaced teats, and, if a boar,

(c) I. be a member of a litter, or a subsequent litter of the same mating (full sib), from which a representative group has attained certain minimum standards of performance under the Record of Performance for Swine regulations and procedures. The minimum qualifications in the initial year, and until new standards are established, shall be:

1. Consume not more than 500 pounds of feed per 100 pounds of carcass gain or 400 pounds of feed per 100 pounds of live weight gain, or gain equivalent to producing a 155-pound carcass (hot weight) in 190 days or less.

2. Carcass quality, as scored under the 1959 standards, equivalent to a score of 68 points for a test litter of two males and two females. Adjustments for sex differenes in carcass quality shall be made in the following manner:

Tested group size	4 pigs scored					3 pigs scored			
Sexes tested	4M 0F	3M 1F	2M 2F	1M 3F	0M 4F	3M 0F	2M 1F	1M 2F	0M 3F
Minimum score required	60	64	68	72	76	60	65	70	76

Or

II. is by an Elite sire and out of an Elite dam. An Elite sire shall be Lacombe boar which has sired a minimum of three litters which have obtained the level of performance given under (c) I, and an Elite dam shall be a Lacombe female which has produced a litter which obtained the levels of performance given under (c) I.

Or

III. is out of an Elite dam and by a boar whose sibs when tested under the Record of Performance for Swine obtained a level of performance at least 10 per cent better than the minimum requirements listed in (c) I, that is:

1. Consume not more than 450 pounds of feed per 100 pounds of carcass gain or 360 pounds of feed per 100 pounds of live weight gain, or gain equivalent to producing a 155-pound carcass (hot weight) in 170 days or less.

2. A carcass score of 76 points for a test litter of two males and two females. For tested litters to other sex combinations the score requirements shall be:

Tested group size	4 pigs scored					3 pigs scored			
Sexes tested	4M OF	3M 1F	2M 2F	1M 3F	OM 4F	3M OF	2M 1F	1M 2F	OM 3F
Minimum score required -	68	72	76	80	84	68	73	78	84

The qualifying standards provided under (c) I and (c) III shall be reviewed annually and revised on the basis of the performance of all Lacombe litters tested during the previous year, the objective being to base the requirements on a moving weighted average performance for these traits for the preceding five-year period.

APPENDIX B

The format on card 1 and card 2.

Card 1.

Column	Information
1 - 2	sire herd
3 - 7	sire registration number
8 - 9	dam herd
10 - 14	dam registration number
15 - 16	month on test
17 - 18	year on test
19 - 20	herd of progeny
21	home testing (1) or station testing (2)
22	number of males tested
23	number of females tested
24 - 26	age on test (days)
27 - 29	age at slaughter (days)
30 - 32	days on test (days)
33 - 35	feed efficiency (feed lb./100 lb. live gain)
36 - 39	carcass length (inches) xx.xx
40 - 42	shoulder fat (inches) x.xx
43 - 45	loin fat (inches) x.xx
46 - 49	loin area (sq. inches) x.xxx
50	code for herd comparison

Card 2.

Column	Information
1 - 5	sire registration number
6 - 10	dam registration number
11 - 15	sire's sire registration number
16 - 20	sire's dam registration number
21 - 25	dam's sire registration number
26 - 30	dam's dam registration number

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